DEVELOPMENT OF A METROPOLITAN SIMULATION MODEL ON SPATIAL ALLOCATIONS OF ACTIVITIES IN FLOW AND STOCK ASPECTS

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PREFACE

It was in 1975 when the author started out the study on a metropolitan simulation model aimed at Kanto Plane of Japan, which has led to the initial version of the model presented here. As that version was also developed under the intention to cover all the economic activities in a metropolitan area, the flow analyzing portion as well as the general construction of the present model is basically inherited from it. However, the problem with the former model was that it was the one to be classified as an engineering model, which was designed to meet the need for predictions given scenarios of transport investments. And its portion to analyze the locations of activities, which may be regarded as the key segment in such models, has not taken the existing economic theories much into account. Thus it was decided in 1985 to fully revise the model to the present form, which was virtually completed by spring 1988.

The present model is designed to be as orthodox as possible both theoretically and in terms of data utilization. With the lack of new modeling techniques, it may appear less appealing to some readers. However, this stems from an effort to guarantee its operationality in any area along with its limited data requirements. As a matter of course, no model could be immunized from compromises in the sense that it should be formulated within the data set available, whose size is limited owing to resource restrictions. In this connection, our model also represents a consequence of such compromises, and there might be better ways to negotiate between theories and data availability. However, it is hoped that the model could have managed to provide a feasible framework for analyzing a metropolitan area.

In conducting the study, the author is indebted to many individuals. In particular, the continuous encouragement of Professor Kozo Amano has been indispensable to complete the study in the form of a dissertation. I would also like to express my gratitude to the other members of my dissertation committee, Professors Kazuhiro Yoshikawa and Norio Okada, for their valuable comments. Professor Masahisa Fujita, who has been one of my advisors at the University of Pennsylvania, also deserves my appreciation since the idea to lead the present model was originated in him. I am also indebted to Professors Hiroyuki Yamada, Hisayoshi Morisugi, Masuo Kashiwadani, and other members of the research group organized in Kansai Area for *Japan Research Center for Transportation Policy* as the discussion on the model at its early stages was of great assistance. Additionally, I must acknowledge Dr. Toichi Kimura that the flow analyzing portion of the model has been evolved from his master thesis at Kyoto University.

Thanks are also due to Mr. Michio Sakai who has cooperated with me in developing the activity model through his master thesis, and Mr. Katsuaki Yoshida who has assisted me conducting the test simulations. Finally, I would like to thank Messrs. Sihil Daluwatte and Ryuji Kakimoto for their help in editing the manuscripts, and Mr. Ryuichi Uchida for his excellent drawings, as well as other countless students at Kyoto and Kumamoto Universities who have in some way helped me complete this dissertation.

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CHAPTER 1

INTRODUCTION

1.1. Disciplines in Location Theory and Operational Models

It might be appropriate to say that the modern location theory stems from the two pioneering works; viz. by von Thünen[1] and Weber[2]. The former discussed the optimal selection of crops to be raised at each location, and the latter argued the location of a manufacturing firm which combines raw materials extracted at given locations. However, both of them considered the market as a predetermined point. And in this regard, their analyses would provide no indications about the spatial competitions, even though the former considered an unspecified number of farmers.

1930's mark the most significant developments in the history of location theory. Among them are Palander[3] and Hoover[4], who criticized Weber's theory of industrial location. Palander generalized the concept of isodapanes to reflect both transport and production costs which correspond to a number of material and consumption sites. And Hoover identified the forms of industrial agglomerations associated with the economic growth, viz. the scale economies within a firm, the localization economies for all the firms within a sector, and the urbanization economies based upon inter-sectorial transactions.[†1]

The study on spatial market was initiated in 1929 by Hotelling as an example of imperfect competition through his famous problem of "ice-cream stands".[5] He demonstrated that his duopolistic competition leads to an unstable and socially suboptimal solution. While Hotelling's market was a line segment, Christaller observed the two-dimensional distribution of

†1. Hoover's book was written after both Hotelling's paper[5] and Palander's book were published. Thus it is natural that he considered a continuous market as well as point markets. However, his emphasis was apparently on the location of individual firms rather than on the market divisions. And in this context, his study could be considered as a refinement of Weber's work.

villages to be in conformity with hexagonal lattices, called the *central place system.*[6] Each village lies at the center of a hexagon which represents the market area of that center. While his expression of spatial monopoly is determined solely by the consumers' behavior, Lösch explicitly considered the suppliers' costs as well.[7] In this regard, the implications of their theories are different despite the resemblance between their market areas.[8] However, their analyses are important in the sense that they have introduced suppliers belonging to various sectors to the market, along with the hierarchies of commodities and centers.[†2]

Meanwhile, there had been virtually no successor to the other pioneer in location theory, von Thünen, until Alonso interpreted the original agricultural land in the context of residential land use.[9] He applied the neoclassical consumer theory to the spatial economy and laid a foundation for the field of research known as the *new urban economics* (NUE),[10] which has been developed in 1970's. Thus we could roughly summarize that the focal points in location theory in the 20th century have been shifted from the optimal location of a single firm to the spatial competition among multiple firms with fixed or uniform distribution of consumers, and then to the equilibrium distribution of consumers.

Despite these developments to theorize about locational activities by geographers and economists, developments in the operational regional models, generally intended to analyze a metropolitan area, had to await the mid 1960's when the digital computers became available. However, partly because many of such efforts were motivated by practical needs, and thus, undertaken by researchers with non-economic backgrounds, the construction of such models have had little to do with the theoretical developments.[11]

†2. In particular, Christaller's system presumes the existence of complete and consistent hierarchies concerning commodities and market areas over which they are to be delivered. Although it appears too restrictive to assume that all the commodities can be classified into a few hierarchies, his philosophy has something in common with the economic base theory, which reflects upon many operational models.

For example, Forrester's *urban dynamics* model[12] had once been widely accepted as a tool to analyze causality among various urban phenomena. However, his framework failed to attract researchers to follow since his results were based on many ad hoc hypotheses, which appear to have been adopted without much reference to the existing economic knowledge.

Among other types of models which managed to attract little successors is the EMPIRIC model developed by Hill for Boston metropolitan area.[13] The model is primarily intended to evaluate the economic impacts of public investments mainly based upon a system of simultaneous linear equations akin to the input-output framework. Although the econometrics is an indispensable tool in regional modeling, it is insufficient to describe the entire system in terms of linear relations.[†3] In particular, a metropolitan model is to differ from a national macro-econometric model in the sense that the zones considered in the former are relatively small so that the spillover effects across them cannot be ignored.

Among those *descriptive models* which are intended to reproduce the real-world distributions of zonal economic indices such as population and employments, the most influential model would be the one developed for Pittsburgh by Lowry.[15] Since its publication in 1964, the model has generated a number of modified or extended versions and come to form a family of models called the Lowry-type models.[†4] The most significant feature of the Lowry model would be the underlying theory of *economic bases.* As the study area of the model is spatially limited, the activity levels of the basic sector which produces commodities tradable with the rest-of-the-

†3. Owing to the advancement of programming technologies, the linearity of the system is no longer a restrictive feature in modeling nowadays. For example, the SAS statistical package has the procedures SYSNLIN or SIMNLIN for the system of nonlinear equations.[14]

†4. Sometimes they are called the Garin-Lowry type models reflecting the person who reinterpreted the original model in the ways that the potentials have been replaced by the constrained gravity models, and that the economic base mechanisms have been clarified through the matrix representations.[16]

world, are to be determined exogenously to the model. Other problems associated with the original model include the following points. i) As the distributions are determined solely from the demand side requirements, no price mechanisms to negotiate with the supplies of land are introduced. ii) The distribution functions are formulated in terms of aggregated macro variables so that the individualistic micro behavior has not been considered in the model. And iii) the model is essentially static to produce the concurrent distributions corresponding to the present exogenous values.

The third point was immediately improved by the Time-Oriented Metropolitan Model (TOMM) which considered the same study area as the original model.[17)] Their approach to simulate the time paths of the stock variables in the model is called the *quasi-dynamic* approach, which has been employed almost in all operational models ever since. As for the first point, the Lowry model avoids the locational competition among agents by presuming the order by which they locate. Although it is not easy to fully describe those competitions in terms of market clearance and price equilibrium, it is relatively easier to incorporate some price indices for spaces into the model. For example, the Southern Kanto model introduced the lot size function which reflects the land value,[18)] and the one by M. Echenique and Partners (MEP) adjusted the demands for floor spaces by explicitly considering rents.[19)] The most theoretically oriented approach would be the one employed by the Detroit prototype model by NBER, where the market is cleared in accordance with the solution from a linear programming problem to minimize the social transport cost,[20)] with the corresponding dual variables being interpreted as the surrogate rents.[†5]

†5. In general, there exists an optimization problem which can reproduce the market equilibrium under the absence of externalities. This is also the case in the Herbert-Stevens model,[21)] which was formulated as a linear programming problem to maximize the net rent revenues. The minimization problem employed in the NEBR model would also be expected to represent the equilibrium residential allocations, but its descriptive performance was not necessarily satisfactory when evaluated as a practical model.

With the evolvement of the entropy maximizing model, it has become a common practice to formulate the distribution model as a constrained gravity model.[22)] While the doubly constrained model is popular in traffic distributions, the singly constrained one would be the choice for the present purposes. The solutions from a singly constrained model share the common functional form as the *logit model*, which is named after the logistic growth curve. Thus it would be advantageous to use the logit type function to obtain the distributive probabilities as it may reflect variables other than distances. At first, the logit model has been applied in the aggregative context, but later the model has come to be applied to the disaggregative cases based on the individualistic behavior. The theoretical justification of such applications was provided by McFadden as the *random utility theory*,[23)] which is regarded as one of the solutions to the second point. The theory demonstrates, in light of statistics of extremes, that the probabilities calculated from a multinomial logit model are closely related to the micro-economic behavior under statistical disturbances.

Recently, a class of operational models has evolved to be capable of analyzing both land use and transportation aspects of metropolitan activities. As there already exists a number of surveys concerning these models,[24),25),26)] we shall refrain from comparing them here. In particular, the work conducted by the International Study Group on Land-Use /Transport Interaction (ISGLUTI) covers comparisons,[27)] from a variety of viewpoints, among nine models which are chosen from typical of modern operational models.[†6] We may refer to some of these models in the next

†6. Out of nine models compared, two seek the normative allocations, i.e., Single Activity Location Model (SALOC) and Technique for Optimal Placement of Activities in Zones (TOPAZ). The rest of the models are descriptive ones intended to simulate the market allocations. They include; Computer Aided Land Use/Transport Analysis System (CALUTAS), Integrated Transportation and Land-Use Package (ITLUP), Leeds Integrated Land-Use Transport (LILT) Model, along with the aforementioned MEP model. The remaining three models are identified by their study areas, viz. the models for Amersfoort (Holland), Dortmund (FRG), and Osaka (Japan).

chapter in comparison with our position to deal with matters relevant to a practical model on the metropolitan activities.

1.2. The Objectives

With the aid of the progressive computer technology, the recent operational models tend to seek a globalization so as to combine the land use and transportation submodels in the efforts to capture the locational interdependencies to some extent. Despite such trends, our objective in this study is to propose yet another metropolitan model, whose focus is set upon the metropolitan land use.[†7] Instead of not explicitly considering the transport sector in detail, we intend to formulate a model which covers the entire metropolitan activities. For instance, the land use models naturally consider allocations of stocks, but not many of them consider the source of such allocations, viz. the investments as a fruit of producing activities. In other words, housing constructions may occur wherever there are demands, but the level of constructions is affected by not only land prices but also the economic climate. Along this line, it would be of particular importance to consider both flow and stock aspects of metropolitan activities within the model in a balanced manner that carries comparable analytical details concerning every item.

One of the focal points in this study stems from the fact that many of the operational models have been motivated by practical needs, and thus, their formulas are not necessarily consistent with the existing economic theories. In particular, it seems there exists a gap between the macro-

†7. In this regard, the present study lies along the extension of the author's master's thesis.[28] While it is based on the data centering about the 1970 population census, the new data set is created using the 1975 and 80 censuses. One of the reasons why we do not utilize the old data set is the conceptual alteration in the income statistics to the system called the new SNA,[29] which results in discontinuance of data prior to 1975. In addition, the detailed housing statistics have become available in the population census only since 1975.

econometric models and the formulas in those operational models, even though the latter usually contain many expressions to be estimated through the econometric approaches. This is because the former mainly analyze the economies, such as the national economies, which are more complete in terms of transfers with outside the study area, while the latter concentrate on the relatively narrow area, such as a metropolitan area, where such transfers are essential. In return, the econometric models for analyzing smaller regions tend to utilize many dummy variables to represent regional disparities,[30] but this implies that those models relinquish to explain the cause of such disparities. In this connection, our objective is to formulate a metropolitan simulation model which is consistent with the existing theories, including the location theory, the input-output analysis, as well as the macro-econometric approach. It may appear less appealing on the ground that the model refrains from incorporating particularly new techniques, but this is a consequence of our objective to make the model coherent to the orthodox approaches.

Each of the problems associated with a metropolitan area accrues from the interactions, either directly or indirectly, among metropolitan activities. The fact that such interactions occur across the zones within the area as well as the activities suggests the need for a comprehensive model which incorporates a multi-regional and multi-sectorial framework. As those interactions would not cease in a single time period, the model must be capable of analyzing the dynamic aspects of activities as well. And the model which is effective in analyzing those problems and assessing the policies as their remedy must possess such features. In other words, the model to be proposed in the study must be *comprehensive* in the sense that it is not only facilitating the individual zones and sectors, but also covering the metropolitan area as a whole with explicit reference to dynamic repercussions. As a matter of course, the smaller the area and the activities are subdivided, the more detailed the information we might get.

However, such a practice will definitely ruin the operationality of the model through the increase in the size of the problem, and simultaneously reducing its reliabilities. As those classifications are closely related to the analytical methods adopted, it is quite important to clarify the configurations of the model.

Chapter 2 is then devoted to the descriptions of those configurations in three respects; the hierarchical composition of space and commodities, the ways to deal with the locational competitions among activities, and the ways to express the dynamism in the model. The balanced input-output analysis is employed as the basic scheme to analyze flow aspects of activities, in response to the hierarchy to be introduced to the model. In addition, the model is recursively dynamic in nature, where the random bid price theory is employed to describe those competitions.

Corresponding to these configurations, *Chapter 3* discusses the problems to be cleared for their materialization including the general construction of the model. The spatial and sectorial classifications are specified concerning the study area, the Kanto Region of Japan, where the data are collected between two census years, 1975 and 80. In addition, the method to calculate the commodity based inflators, a nonsurvey technique to modify the coefficients relevant to the input-output analysis, and the possibility to apply the parameters estimated at one spatial level to another are discussed.

As the model is constructed from three major model blocks; the regional frame, the activity and the location models, the succeeding three chapters are devoted to the descriptions of respective blocks. We open the discussion with the activity model in *Chapter 4*, which combines the three level rendition of the balanced input-output analysis, called the three level input-output model, and the distribution models concerning the productions and consumption items. Followed by is *Chapter 5*, which is devoted to the descriptions of the regional frame model, where the regional values

of sectorial employments and the final demand items are to be determined.

The location model formulated in *Chapter 6* comprises five submodels, among which the basic location submodel is most fundamental as it allocates land to the locating activities, defined as those occupying urban land. The fixed capital and employments are calculated in accordance with the land allocations, and the employments in the rest of the activities as well as spatial allocations of investments are determined in the auxiliary location submodel. While the model explicitly considers the demolitions of activities, the residential choices are considered simply in the form of the commuting OD distributions.

Chapter 7 reports the results of the test simulations, which may be called quasi-final as being confined to certain limitations. Two types of tests are conducted; the flow simulations to mainly test the performance of the activity model, and the flow and stock simulations intended for the location model. And finally, the summary of the study and the conclusion are stated in *Chapter 8*. Naturally, our results are bounded on the data utilized for specifying the model formulas, but it is hoped that the philosophy of constructing the model could be versatile enough to be applied to a variety of circumstances.

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CHAPTER 2

CONFIGURATIONS OF A METROPOLITAN SIMULATION MODEL

The modern history of operational models for a metropolitan area is said to be originated in the Lowry model, whose features could be summarized into the following three points. That is, it is based on the economic base theory, the model is essentially distributive, and is static in nature. In light of the discussion in the previous chapter, we examine each of these, which are to constitute focal points in building an operational model aimed at analyzing a metropolitan area. Consequently, our position to deal with the hierarchies of space and commodities, the locational competition, and dynamism within the realm of our model will be clarified.

2.1. Hierarchical Composition of Space and Commodities[1)]

The present study is aimed at building a general simulation model on the allocations of metropolitan activities. As one of the focal points in the model is to describe the land use within the study area, this category of models is often called collectively the *land use models*. While the pioneering work of the kind is attributable to Lowry,[2)] many of the succeeding models naturally inherit the Lowry traditions as mentioned in the previous chapter. One of such traditions may be interpreted as the *economic base theory*[3)], which dichotomizes the industrial activities into the basic activities, which are to support the regional economy, and the nonbasic or retail ones. By assuming that the former are in some way allocated from outside the model, the model is expected to concentrate on the allocation of the latter. Such a convention seems justifiable as it is generally impossible to determine the activity levels of the basic activities, whose products are to be traded beyond a metropolitan area, only from the local information. Nevertheless, we observe that this would not necessarily provide a reasoning to preclude the possibility to endogenously distribute the activities over the zones in the area. Accordingly, the model to be proposed here should be capable of distributing all the activities over the zones unless their allocations are indeed prespecified.†1

Meanwhile, although it is conceptually possible to dichotomize the activities on the ground whether their activity levels are determined locally, the border between the basic and nonbasic activities are quite ambiguous in the sense that the completeness of the activities, in terms of excess demands, depends on the extent of the study area. One way to negotiate with this type of ambiguity would be further to classify the activities into more than two categories.†2 In this connection, the *central place theory* proposed by Christaller attracts our attention as it deals with a hierarchical composition of centers and commodities.[5] Theoretically, Lösch's market is preferable to Christaller's perception as the latter lacks in supplier's viewpoint.[6] In contrast to the somewhat heuristic agglomeration of centers suggested by the former, Christaller provides with a well-organized system of centers, where a higher center supplies all the commodities available at lower centers. Despite his presumption on unidirectional ordering of commodities appears so purposeful that it is designed to lead to mutually exclusive and spatially consistent market areas, his approach is still interesting from the position to study the relationship between agglomeration and economies of scope.

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†1. That is, the model should be flexible in the sense that some portion of the values to be distributed could be withheld for non-competitive allocations in accordance with the social policy. This suggests the importance of interfaces in a practical model with the exogenous policies. In addition, it is possible to determine some of the activity indices in the basic sector endogenously by incorporating a macro-econometric submodel, which is in charge of interfacing the study area with the rest-of-the-world.

†2. Apparently, such a practice does not reduce the ambiguity associated with the borders. However, when we consider more than two categories, we might introduce the distinction between "highly" basic activities and "somewhat" basic ones. The study to identify the basic activities through the locational quotient and other objective indices is known as the B-N analysis.[3] However, it is usually difficult to identify the tertiary industries as the basic activities as far as such indices are confined to the ordinary economic statistics.

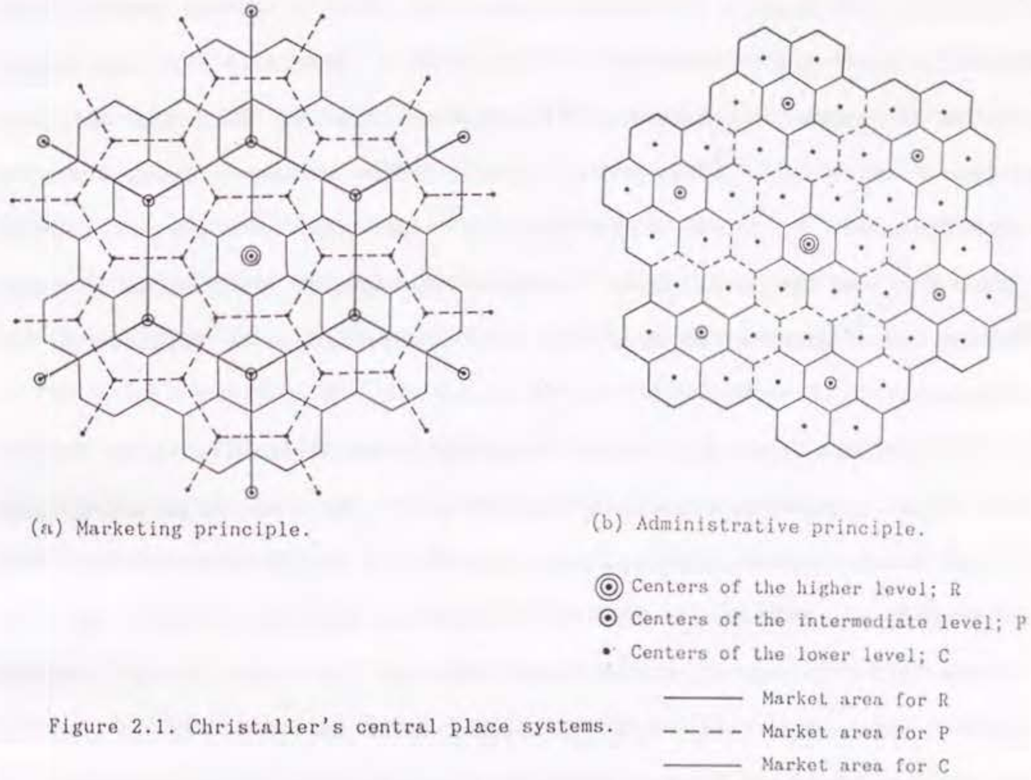

Figure 2.1. Christaller's central place systems.

According to the Christaller's theory, a city is located at the center of a market area to which the city supplies commodities. The commodities are classified by their reaches determined by the consumer distribution, transportation, and so forth. He introduced three principles to arrange centers and their markets.[7] i) The *marketing principle* is to distribute all the commodities from the least number of centers, where some of the market areas corresponding to a lower commodity is divided among the three of the higher market areas as shown in Figure 2.1(a). While a similar situation is also observed in ii) the *transport principle*, it is not likely that the smallest zone such as a daily activity zone is further subdivided to become parts of higher markets. In this respect, it is appropriate for our purposes to regard the area be organized in accordance with iii) the *administrative principle*, where a lower level zone belongs to a single higher market as shown in Figure 2.1(b).†3 A perfect areal division concerning the market areas is observed with this principle, where each higher center controls six surrounding lower centers without being interfered by other higher centers. As the above is generally the case in the system of local jurisdiction, this type of spatial hierarchy has been employed in a number of practical models. For instance, among the nine ISGLUTI models,[8),9)] the Dortmund model[10)] and the two Japanese models, CALUTAS[11)] and the Osaka model[12)], employ the spatial hierarchies of three levels, which require the zonal allocation processes to be executed in two phases.

Along this line, the central place system still appears to be useful for explaining the hierarchical composition of the real world metropolis. As the primary factor which regulates the system is the extent of the area over which a commodity or service is supplied from each center, we also define the hierarchy of activities in our model in terms of their market areas. Accordingly, the spatial hierarchy is to be determined in response to the area where the demand and supply for each commodity or service meet. When we assume a hierarchical composition of activities and space, the appropriate analytical method in an operational model could be the one incorporating a multi-phased distribution process for those activities. For instance, it is also necessary to choose a flow analyzing method which is compatible with such a hierarchy, as the model is intended to describe both stock and flow aspects of metropolitan activities. In this regard, the balanced input-output (BIO) model proposed by Leontief would be the most appealing to our requirements.[13)]

The model was developed so as to analyze the intranational trades without a detailed interregional table, and was the first to successfully evaluate the spatial impacts due to the post-war arm cuts.[14)] Nevertheless his approach has had few successors with the increasing availability of

†3. As to be seen in Section 3.1, we consider the spatial hierarchy of the study area in three levels corresponding to the fact that the most dependable regional statistics are available at the prefectural level. And no cities, wards or townships affiliate with more than one prefecture.

interregional tables. When it comes to the study of a relatively small region, such as a metropolis, the BIO approach is still found effective in practice by virtue of its lesser data requirements as compared with the other four interregional input-output frameworks.[15)] Suppose m and n denote the numbers of sectors and subregions constituting the study area, respectively. Then the data requirements in the two popular frameworks, the Isard model and the Chenery-Moses model, count up to $(mn)^2$ and $mn(m+n)$ elements of the input and/or trade coefficients combined, respectively. Meanwhile, the BIO model could manage to project the spatial allocations of productions, consumptions and investments among subregions with only $m(m+2n)$ of such elements.[16)] Even with relatively abundant regional statistics available in Japan, it is difficult to obtain detailed information concerning inter-sectorial and inter-zonal transactions at the municipality level, the lowest spatial level subject to our study. Hence, we employ the BIO approach as the primary analytical tool in our flow analysis.[†4]

2.2. Locational Competitions

Since the pioneering work by Lowry[2)], most of the operational land use models used to describe the locational process as the locating activities, such as industrial sectors or household types, to choose their locations. However, as a zone which is preferred by some activity is likely to be equally desirable for other activities, there should be a conflict over the limited space available in the zone. The Lowry model and some successive models avoid such competitions, at least in part, by introducing a prespecified priority to their locational processes as mentioned in the previous chapter.[†5] Another way to preclude them is to assume an exclusive zoning under which a zone is earmarked for the use of

†4. In practice, the BIO model is modified to the three-level input-output (3LIO) model to meet the information availability in our study area. In particular, the way to obtain the intraregional trades is fairly different from the original model. The full description of the 3LIO model, including its basic assumptions, will be given in Section 4.1.

prespecified locators. However, partly because such a zoning cannot be specified apart from the market reality, and because we must still face the conflict among sectors within each zoning category, we have to confront the problem associated with the locational competitions, viz. how to negotiate the excess demands with the limited spaces.

Meanwhile, most of the existing models have regarded the locational demand in an aggregative way, where the model would calculate the shares by which the demand is distributed over the zones. When McFadden introduced the *random utility theory*,[17)] efforts to formulate the locational process using it followed immediately, either in a disaggregative or an aggregative context.[†6] In those models, each agent in the market chooses the location(s) where he/she can attain the highest level of utilities. In this respect, the models are essentially distributive in effect, even though each choice is discretized. Then three problems might be relevant to this approach. i) In practice, the utility function would only be estimated from the revealed choices, which are the results of negotiations with other parties under various regulatory constraints. Accordingly, the function corresponds to an indirect utility, which does not represent the real preferences. ii) As each zone constitutes an alternative, the model projections would be unstable when the study area is divided into relatively small zones. Thus it might be necessary to employ a nested model to facilitate many zones. iii) Although the function is based on the equilibrium data free from excess demands, readjustment process would still become necessary when the demand to a zone exceeds its capacity.

The random utility approach is not the only way to describe the micro behavior in locational processes. In particular, the Alonso model provides a theoretical background to the urban economics by analyzing the static residential competition through its neoclassical approach, where the market is cleared deterministically by means of the bid rent function.[20)] Incidentally, CALUTAS manages the locational competition at the lower spatial level in accordance with the "locational surplus", which is defined as the difference between the "expected utility" and the actual land price to be paid by each agent.[11)] Here the former can be interpreted as a willingness-to-pay from its monetary denomination. Despite the efforts to give a proper economic reasoning to the locational surplus,[21)] it has been clarified that the allocation based on it corresponds to a kind of second-best solution under a rent control policy.[22)] In other words, we can hardly identify the allocation prescribed by the locational surplus with the Alonso-type equilibrium from a viewpoint of the static theory, keeping its empirical significance aside.

Ellickson proposed an alternative way to view the locational process known as the *random bid price theory*.[23)] According to his formulation, the lot is supposed to choose the agent who would present the highest bid price including probabilistic disturbances. Incidentally, such a way of thinking is in conformity with the Alonso model as we can observe from some of its equilibrium conditions.[†7] In addition, as the choices based on random bid

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†5. With exceptions of the Amersfoort model, where the competition is precluded owing to the exogenous employments and the unique housing type, and the Dortmund model, where the locating priority is determined endogenously based on the land profitability, five out of seven descriptive models in ISGLUTI reflect such priorities in some way. While some models employ the traditional basic/non-basic ordering, the others assume rather a broad one, where industrial locations precede the residential ones, but no sector is granted a priority within each category.

†6. For example, Hayashi *et al.* tries to formulate the industrial location, which is highly discrete by nature, as a nested multinomial logit model based on random utilities.[18)] On the other hand, when we extend our perspectives to the aggregative applications of random utilities, the Chicago Area Transportation-Land Use Analysis System (CATLAS) developed at Northwestern University must be referred to as one of the early models which fully utilize the multinomial and/or nested logit probabilities.[19)]

†7. For simplicity, we confine ourselves to the static context.[24)] Suppose we denote the equilibrium rent and bid rent function of class i at location r by $R(r)$ and $\Psi_i(r)$, respectively, and the number of class i residents at r by $n_i(r)$. Then with the agricultural opportunity rent, R_A, the relevant conditions are as follows.

$$R(r) = \max\{\max_i \Psi_i(r),\ R_A\} \text{ and } [R(r)-\Psi_i(r)]n_i(r) = 0.$$

prices never violate space restrictions, contrarily to the case of random utilities, no specific process to negotiate with the land availability is required with this theory.†8 Although the theory by itself is designed to describe disaggregate choices, it is quite possible to apply it to the aggregate probabilities similarly as CATLAS formulates the random utilities in an aggregative context.[19)] Then the number of alternatives is given by the categories of locating activities, which would be rather limited as compared to the number of zones. Along this line, we employ the aggregative application of the random bid price theory as the basic analytical framework to describe locational competition.[25)]

Suppose that the agent i proposes a bid price $\Psi_i(z^d)$ to a unit of land in zone d characterized by the attributes z^d. Then if the disturbance terms, ε_i and ε_j, follow an identical and independent Weibull or Gumbel distribution (IIGD), the probability of the agent i's locating in zone d would be given by a multinomial logit model.[26)]

$$p(i|z^d) = \text{Prob}\{\Psi_i(z^d)+\varepsilon_i \geqq \Psi_j(z^d)+\varepsilon_j,\ \forall j\neq i\} = \frac{\exp \Psi_i(z^d)}{\sum_j \exp \Psi_j(z^d)} \qquad (2.1)$$

In the disaggregative context, the parameters relevant to the above expression may be determined primarily through either maximum likelihood or discriminant approaches, which are suitable to deal with discrete

(continued)

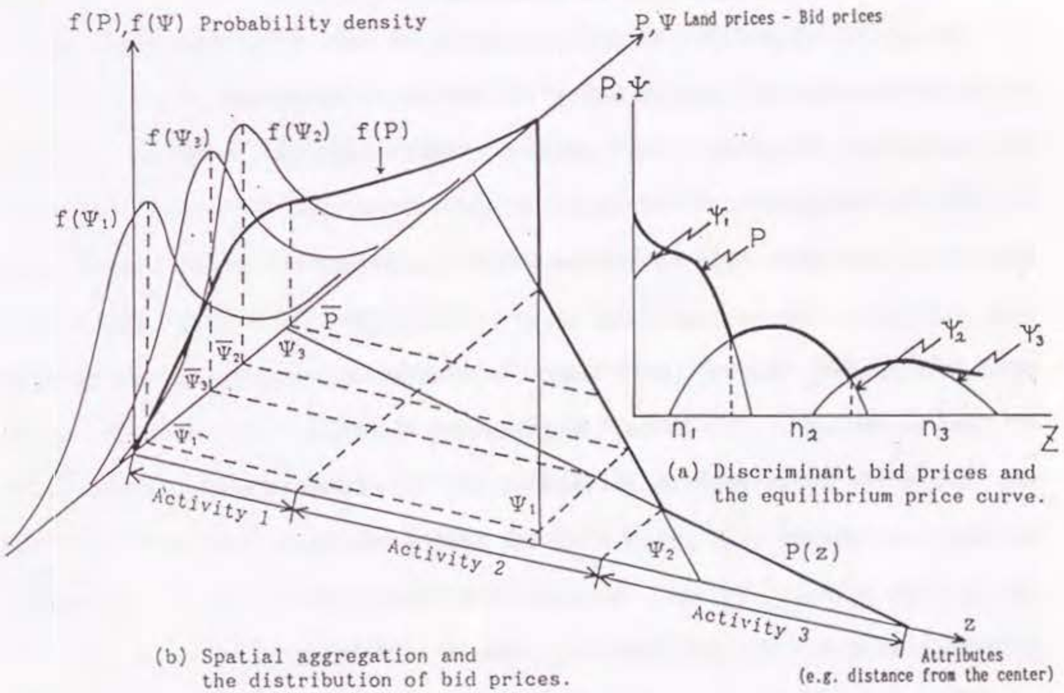
The first condition indicates that the equilibrium rent is equal to the maximum bid rent if it exceeds the opportunity rent. And the second one implies that each class has to present the highest bid for it to become the actual resident at the site.

†8. In return, it is probable that a particular activity is assigned either excessive or insufficient amount of land throughout the study area. In the context of Alonso model, this can be explained as follows.

While the land constraint, $\sum q_i(r)n_i(r) \leqq L(r)$, is automatically satisfied with the random land price formulation, the population constraint, $\int n_i(r)dr = N_i$, is not. Here $L(r)$ is the area available to the residential purposes, and N_i is the number of class i residents in the entire city. In contrast, the latter constraint is automatically satisfied with the random utility approach as it determines the probabilities by which agents choose the zones.

observations. When it comes to apply eq.(2.1) to the aggregative behavior, it would be appropriate to consider that every unit of land is put up at a separate auction. Then the LHS of the above expression can be interpreted as the portion of land in the zone occupied by the i-th activity.

It must be noted that the bid price function in the Ellickson's model is discriminant in nature, and thus, has no direct linkage with the actual land prices. Lerman and Kern suggested to extend the Ellickson's estimation in the way to establish such a linkage by incorporating a flavor of regression into the discriminant process.[27)] As their approach is to regress the bid prices to the actual price level wherever the demand is revealed, the estimated land price profile may be depicted as in Figure 2.2(a), where the attributes in bid prices are assumed to be representable by the distance z from the CBD.†9 We can observe that the discriminant



(a) Discriminant bid prices and the equilibrium price curve.

(b) Spatial aggregation and the distribution of bid prices.

Figure 2.2. The random bid price model and aggregate zone.

†9. Again for simplicity, the figures are based on the static bid rent curves. When the city is stationary in the sense that the path prescribed by the perfectly myopic foresights is fully realized, a bid price curve will have a similar profile as a static bid rent curve.

nature of bid prices is still maintained in the Lerman-Kern model, and thus, it is not appropriate to regard them as those in the Alonso-type models as far as the disaggregative behavior is concerned.[28)]

In the aggregative context, however, it is possible to make the discriminant bid prices compatible with the Alonso-type ones as Figure 2.2(b) illustrates. Suppose that each agent in a city is to compete individually for the land whose only attribute is the distance from its center. Then we might have the Alonso-type bid price curves Ψ_i within the city, which are decreasing w.r.t. z, as depicted on the P-z plane. It is well-known that the parcels of land occupied by each activity are spatially separable at the static equilibrium as seen along the z-axis. However, when each bid price curve for the agents, belonging to an activity i, is aggregated over the zone, it is possible to view the probability distribution of bid prices $f(\Psi_i)$ as the discriminant ones as shown on the f-P plane.

It must be noted that each distribution is defined on the range of bid prices by an activity corresponding to the entire city, and not limited to the places it prevails. For instance, the commercial activity C might present the highest bids in the city as far as the "revealed" bids are concerned, but this does not necessarily imply that it could present the highest bids to the average land in the city. Thus its average bid to the aggregate zone $\bar{\Psi}_C$ may be lower than the residential one $\bar{\Psi}_R$ as the portion of land occupied by the former is generally limited. In addition, since the land price curve P(z) is defined as the upper envelope of the bid price curves, the average land price $\bar{P}$ in the zone necessarily exceeds any of the average bid prices. In this respect, the random bid prices to the aggregate zone must not be confused with those in the disaggregative context.

Now we turn to the next question as to how these random bid prices are related over a system of cities. Figure 2.3 depicts the Alonso-type bid prices Ψ_i^d in each city d for two activities, i=C and R, along with the division of land therein. From the above discussion, those bid prices can

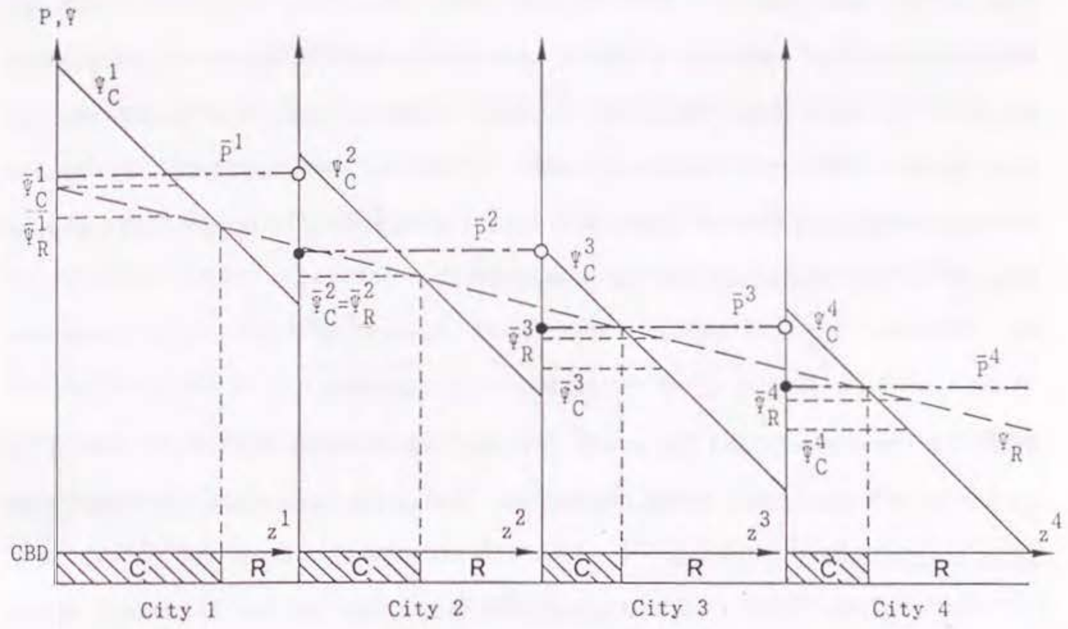


Figure 2.3. The bid prices and average land prices across aggregate zones.

be aggregated over the city to generate the average bid prices $\bar{\Psi}_i^d$ and the land price $\bar{P}^d$. Suppose that city 1 is so dominating that its center can be regarded as the CBD of the system. Then the sequence of aggregate land prices would constitute a step function which is decreasing from the CBD as seen across the cities, and a similar argument also applies to the sequences of aggregate bid prices.

Meanwhile, when the random bid price theory is employed to determine the allocations of land, it is appropriate to consider that the industrial and housing capital stocks, or the numbers of employees and residents are distributed depending on the land. Recalling the fact that the land in an aggregate zone is far from uniform in reality, it does not seem so meaningful to consider the intermediate spatial level to secure a multi-phased process concerning land. Hence, on the contrary to the flow analysis, we employ a single-phased distribution process concerning stock variables, which are preceded by the allocations of land at the municipality level.

It is noteworthy that the zonal land price P is obtained as the average of the locators' bid prices rather than the maximum. In this connection, it is possible to shift the bid prices for a zone calculated by eq.(2.1) to make their weighted average coincide with the zonal average land price. Here the aggregate share ρ_i^d of the i-th activity in zone d calculated by eq.(2.1) is invariant with the addition of zonal shift parameter B^d to the discriminant bid prices Ψ_i^d.

$$\rho_i^d = \frac{L_i^d}{\Sigma_j L_j^d} = \frac{\exp \Psi_i^d}{\Sigma_j \exp \Psi_j^d} = \frac{\exp(\Psi_i^d+B^d)}{\Sigma_j \exp(\Psi_j^d+B^d)} \qquad (2.2)$$

Then if the zonal land price VL^d and the land area occupied by the i-th activity L_i^d are known, we can calculate the shift parameter for the zone from the following relation.

$$VL^d = \Sigma_i(\Psi_i^d+B^d)L_i^d/(\Sigma_i L_i^d) \qquad (2.3)$$

We employ the first three terms of eq.(2.2) as the basic formula to describe the locational competition in the model.

2.3. Expression of Dynamism

While the Lowry model was developed for describing a static equilibrium of land use, many of the succeeding models have been developed as *quasi-dynamic* models as mentioned in the previous chapter. Here the term "quasi-dynamic" would imply that the model is short of some qualifications associated with "real" dynamic models, viz. some kind of foresights are introduced to *all* the agents in the model. In particular, the following two respects appear to be relevant.

i) While some of the agents behave under clear foresights, others are assumed to behave myopically. For example, in the theoretical model of urban land use, it is commonly assumed that the developers' decisions are based on long-term foresights, but households are simplified to behave in a totally myopic manner.[29)]

ii) The model considers the foresights in a very limited way such that the functions to determine the allocations of economic indices are based on the

lagged information from one or two periods. Concerning the stock variables, it is desirable that such allocations are made in terms of increments, but it is a common practice that the model is designed to distribute the gross amounts, rather than the increments, every period.

An operational model which is quasi-dynamic naturally becomes a one technically called a recursive dynamic model. Hence, the metropolitan land use model to be proposed in this study also belongs to this category. As we shall return to its general construction in Section 3.2, we here confine ourselves to a very rough sketch of our model, which is composed of three major model blocks. Figure 2.4 illustrates that the *location model* is executed at the beginning of each period to distribute the stock aspects of macro framework set by the *regional frame model*. This implies that the former model is supposed to provide an arena for the economic activities in the flow sense. The *activity model* is responsible for determining the spatial allocations of flow variables onto the arena, which is assumed to be held fixed throughout each period. And each block must be capable of incorporating the exogenously given policy variables. Hence, we can observe that the activity model is essentially static in the sense that it deals with the flow variables which have to be cleared within a period while the location model requires dynamic formulations by itself. The model as a whole is recursively constructed so that each block is furnished

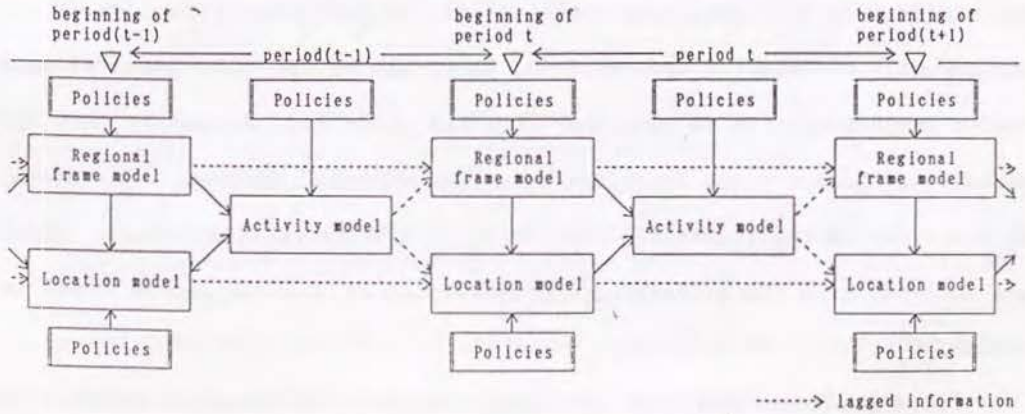


Figure 2.4. The basic flows in a quasi-dynamic simulation.

with the necessary information in the form of predetermined endogenous variables, including lagged ones, as the simulation proceeds.

In connection with the second point, there exist essentially two alternative ways to consider the LHS of eq.(2.1), which represents the share of land in zone d to be occupied by the i-th activity. Those are,

(a) the share in terms of stocks; $\rho_i^d = L_i^d/LF^d$, and

(b) the share in terms of stock increases; $r_i^d = \Delta L_i^d/LAD^d$,

where L_i and ΔL_i are the area occupied by the i-th activity and its increment in a period, respectively, and LF is the area of inhabitable land. As we consider that demolitions take place at the very beginning of each period, LAD is the land available to the locators taking the area released from removal of the i-th activity ∇L_i into account.

$$LAD^d = LF^d - \Sigma_i L_{i(-1)}^d + \Sigma_i \nabla L_i^d \tag{2.4}$$

Naturally, it is theoretically desirable to employ the ratio (b) when we try to describe the locational process as a truly dynamic one. In that case, an accumulation of long-term data on the increments in land use would be indispensable. In particular, when the simulation is based on a relatively short cycle, such as a year, it is difficult to obtain stable estimates from such increments, which are quite fluctuating when compared with the land use data as stocks. It must be noted that the present land use is an accumulation of many locational choices made through the history, and could noway represent the result of the market competitions which are concurrently efficient. Nevertheless, by virtue of the fact that much more stable projections can be expected with the ratio (a), we employ this for estimating the bid price functions as a "second-best" measure. In return, we would employ the incremental ratios r_i^d in the actual simulations, which are obtained from the difference approximations of the bid prices based on stocks, $\Psi_i^d(t)$.

For expository purposes, we first consider the formulas based on continuous time following Fujita.[29] Suppose x_i^d denotes the number of

agents belonging to the i-th activity who locate in zone d, and u_i^d and v_i^d denote the construction and demolition speeds, respectively. Then the change in the number of locators is expressed by the state equation,

$$\dot{x}_i^d = u_i^d - v_i^d = u_i^d - \nu_i^d x_i^d,$$

where ν_i^d is the demolition ratio of the existing stock for a unit time. We further assume that k_i^d and s^d denote the lot size of the i-th activity and the inhabitable land in zone d, respectively. Then eq.(2.2) reduces to the following ratio, where the subscript 0 identifies the reservation demands by the non-urban uses such as agriculture.

$$\rho_i^d = \frac{\exp(\Psi_i^d)}{\Sigma_{j=0}^m \exp(\Psi_j^d)} = \frac{k_i^d x_i^d}{s^d} \tag{2.5}$$

Meanwhile, the locational probability for the stock increments are given by

$$r_i^d = \frac{k_i^d u_i^d}{s^d - \Sigma_{j=1}^m k_j^d (x_j^d - v_j^d)} = \frac{k_i^d (\dot{x}_i^d + \nu_i^d x_i^d)}{s^d - \Sigma_{j=1}^m k_j^d (1-\nu_j^d) x_j^d}\ . \tag{2.6}$$

When we regard k_i^d and s^d as constants, the change in stock can be calculated by differentiating eq.(2.5) w.r.t. the time.

$$\dot{x}_i^d = \frac{s^d}{k_i^d} \frac{d}{dt}\left(\frac{\exp(\Psi_i^d)}{\Sigma_{j=0}^m \exp(\Psi_j^d)}\right) = \frac{s^d}{k_i^d} \frac{\exp(\Psi_i^d)}{\Sigma_{j=0}^m \exp(\Psi_j^d)}\left(\dot{\Psi}_i^d - \frac{\Sigma_{j=0}^m \dot{\Psi}_j^d \exp(\Psi_j^d)}{\Sigma_{j=0}^m \exp(\Psi_j^d)}\right)$$

Incorporating the above into eq.(2.6), we have the following probability for the urban activities, i = 1, ..., m,

$$r_i^d = \frac{\exp(\Psi_i^d)}{\exp(\Psi_o^d) + \Sigma_{j=1}^m \nu_j^d \exp(\Psi_j^d)}\left\{\dot{\Psi}_i^d + \nu_i^d - \frac{\Sigma_{j=0}^m \dot{\Psi}_j^d \exp(\Psi_j^d)}{\Sigma_{j=0}^m \exp(\Psi_j^d)}\right\}, \tag{2.7a}$$

while the reservation probability can be calculated as follows.

$$\begin{aligned} r_o^d &= 1 - \sum_{i=1}^m r_i^d = \frac{s^d - \Sigma_{i=1}^m k_i^d (x_i^d - v_i^d) - \Sigma_{i=1}^m k_i^d u_i^d}{s^d - \Sigma_{i=1}^m k_i^d (x_i^d - v_i^d)} \\ &= \frac{\exp(\Psi_o^d)}{\Sigma_{i=0}^m \exp(\Psi_i^d)} \frac{(1+\dot{\Psi}_o^d)\Sigma_{i=1}^m \exp(\Psi_i^d) + \{\exp(\Psi_o^d) - \Sigma_{i=1}^m \dot{\Psi}_i^d \exp(\Psi_i^d)\}}{\exp(\Psi_o^d) + \Sigma_{i=1}^m \nu_i^d \exp(\Psi_i^d)} \end{aligned} \tag{2.8a}$$

In practical applications, we might use equations which correspond to the difference approximations of eqs.(2.7a) and (2.8a). However, since nonnegativity of these approximations is not guaranteed, we will use the following expressions instead.

$$r_i^d = \frac{1}{A^d}\left[\frac{\exp(\Psi_i^d)}{\exp(\Psi_o^d)+\Sigma_{j=1}^m \nu_j^d \exp(\Psi_j^d)} \max\{\Delta\Psi_i^d + \nu_i^d - \frac{\Sigma_{j=0}^m \Delta\Psi_j^d \exp(\Psi_j^d)}{\Sigma_{j=0}^m \exp(\Psi_j^d)}, 0\}\right], \quad (2.7b)$$

$$r_o^d = \frac{1}{A^d}\left[\frac{\exp(\Psi_o^d)}{\Sigma_{i=0}^m \exp(\Psi_i^d)} \frac{\max\{(1+\Delta\Psi_o^d)\Sigma_{i=1}^m \exp(\Psi_i^d)+\{\exp(\Psi_o^d)-\Sigma_{i=1}^m \Delta\Psi_i^d \exp(\Psi_i^d)\}, 0\}}{\exp(\Psi_o^d)+\Sigma_{i=1}^m \nu_i^d \exp(\Psi_i^d)}\right], \quad (2.8b)$$

where A^d is a constant to keep $\Sigma_{i=0}^m r_i^d = 1$.

When we consider the backward differences, the bid price Ψ_i^d is to be evaluated at time t, and its difference is given by $\Delta\Psi_i^d(t) \equiv \Psi_i^d(t)-\Psi_i^d(t-1)$. As we have seen in the previous section that Ψ_i^d is discriminant by itself, and thus, it can be regarded as a non-dimensional variable. Accordingly, $\Delta\Psi_i^d$ becomes comparable with the demolition ratio ν_i^d as both share the common dimension of $[T^{-1}]$.

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CHAPTER 3

MODEL CONSTRUCTION AND PRELIMINARY CONSIDERATIONS

Considering the configurations of a metropolitan model discussed in the previous chapter, it is now possible to describe the outline of the model. After defining the classification of hierarchies in spatial units and activities, the overall construction of the model is presented. In addition, several preliminary subjects, which are considered to be indispensable in operating the model for a metropolitan area, are also discussed. The nonsurvey method to obtain proper coefficients for the study area related to the input-output analysis is among such subjects.

3.1. Classification of Localities and Activities

The model to be constructed in this study is aimed at simulating the allocations of the flow and stock aspects of urban activities in a metropolitan area. In this regard, the spatial units considered here should be small enough to follow the changes in urban spatial structures. Supported by the increasing availability of data collected for the third-level meshes (approximately 1 square kilometer each), some of the recent Japanese models (Nakamura, Hayashi and Miyamoto[1], and Amano, Toda and Abe[2], for example) employ those meshes as the minimal spatial units. However, when we consider such economic indices as income or expenditures, which are hardly captive to a location, it is difficult to obtain dependable statistics at that level. While many statistics are available on the basis of local jurisdictions such as cities, wards, townships and villages, our model often requires detailed data which are available only for cities and wards.

The Japanese local governing system consists essentially of three hierarchical levels. That is, the metropolitan or prefectural governments are subordinate to the national government, but have jurisdictions over the governments of special wards, cities, townships and villages. As all the regional statistics are available at the prefectural level, it is beneficial to consider the prefectural data as the control totals for those of lower jurisdictions constituting each prefecture. And it is possible to estimate the data for townships and villages using the prefectural ones. However, by regarding these lowest local jurisdictions as the minimal spatial units in our model, we must face the problem of diminishing statistical reliability due to errors associated with such estimations. In this connection, we regard the area which consists of at least one city or ward as a core and surrounding townships and/or villages, if any, as a minimal spatial unit. The unit is called a C-level zone since the area approximately corresponds to an old county. Incidentally, it is natural to analyze the study area in three levels corresponding to the hierarchy of the governing system. The metropolis or a prefecture is regarded as the medium spatial unit called a P-level zone, and the study area as a whole is regarded as the highest one; the R-level zone or Region.

As the study area, we employ the Kanto Region comprising Tokyo Metropolis and six prefectures surrounding it. Accordingly we have seven P-level zones, among which Tokyo and the southern three prefectures (Saitama, Chiba and Kanagawa) are subdivided into 10 to 14 zones as shown in Table 3.1.†1 The northern three prefectures are left undivided since we consider subdivision of the southern prefectures, where most of the economic activities in the Region concentrate, suffices the aim of our study to demonstrate the operationality of hierarchical construction of the model. Consequently we have a total of 51 zones, 48 of which belong to the C-level.

On the other hand, the industrial activities are categorized into 35

†1. Tokyo Metropolis has jurisdiction over the remote islands of Izu and Bonin archipelagoes identified by Zone 615. According to the 1980 population census, the population of the zone amounts to 33674, which merely corresponds to 0.29% of the metropolitan population. Although we exclude the zone from our study area, the amounts correspond to it are redistributed proportionally over the remaining 14 zones to maintain the statistical consistency at the metropolitan level.

Table 3.1. Classification of zones employed in the study.

Prefectures	C-level Zones	Cities, Wards, Townships and Villages	Centroid Station
1. Ibaraki	100 Ibaraki	No subdivisions are considered for Northern three prefectures.	Mito
2. Tochigi	200 Tochigi		Utsunomiya
3. Gumma	300 Gumma		Maebashi
4. Saitama	401 Urawa	Kawaguchi, Urawa, Omiya, Yono, Warabi, Toda, Hatogaya	Urawa
	402 Kitaadachi	Konosu, Ageo, Okegawa, Kitamoto, Kitaadachi County	Okegawa
	403 Tokorozawa	Kawagoe, Tokorozawa, Sayama, Asaka, Shiki, Wako, Niiza, Fujimi, Kamifukuoka, Oi, Miyoshi	Shiki
	404 Hanno	Hanno, Iruma, Sakado, Moroyama, Ogose, Tsurugashima, Hidaka, Naguri	Hanno, Higashihanno
	405 Hiki	Higashimatsuyama, Hiki County	Higashimatsuyama
	406 Koshigaya	Iwatsuki, Kasukabe, Soka, Koshigaya, Yashio, Misato, Matsubushi, Yoshikawa, Showa	Shinkoshigaya, Minamikoshigaya
	407 Kuki	Kuki, Hasuda, Kurihashi, Sagimiya, Satte, Sugito, Minamisaitama County	Kuki
	408 Kitasaitama	Gyoda, Kazo, Hanyu, Kitasaitama County	Hanyu
	409 Fukaya	Kumagaya, Honjo, Fukaya, Kodama & Osato Counties	Fukaya
	410 Chichibu	Chichibu, Chichibu County	Chichibu
5. Chiba	501 Chiba	Chiba, Yachiyo	Chiba
	502 Funabashi	Ichikawa, Funabashi, Matsudo, Narashino, Kamagaya, Urayasu	Funabashi
	503 Kashiwa	Noda, Kashiwa, Nagareyama, Abiko, Sekijuku, Shonan	Kashiwa
	504 Narita	Narita, Imba, Shiroi, Inzai, Motono, Sakae	Narita
	505 Sakura	Sakura, Yotsukaido, Shisui, Yachimata, Tomisato	Sakura
	506 Ichihara	Ichihara	Goi
	507 Kimitsu	Kisarazu, Kimitsu, Futtsu, Sodegaura	Kimitsu
	508 Katori	Sawara, Katori County	Sawara
	509 Kaiso	Choshi, Yokaichiba, Asahi, Kaijo & Sosa Counties	Asahi
	510 Sambu	Togane, Sambu County	Naruto
	511 Sotobo	Mobara, Katsuura, Chosei & Isumi Counties	Ohara
	512 Awa	Tateyama, Kamogawa, Awa County	Tateyama
6. Tokyo	601 Chiyoda	Chiyoda, Chuo, Minato	Tokyo, Otemachi
	602 Shinjuku	Shinjuku, Bunkyo, Shibuya, Toshima	Shinjuku
	603 Koto	Taito, Sumida, Koto, Arakawa	Asakusa
	604 Ota	Shinagawa, Ota	Omori
	605 Setagaya	Meguro, Setagaya	Sangenjaya
	606 Suginami	Nakano, Suginami	Asagaya
	607 Itabashi	Kita, Itabashi, Nerima	Tobu-Nerima
	608 Katsushika	Adachi, Katsushika, Edogawa	Aoto
	609 Mitaka	Musashino, Mitaka, Chofu, Komae	Mitaka
	610 Tachikawa	Tachikawa, Fuchu, Akishima, Koganei, Kokubunji, Kunitachi	Tachikawa
	611 Kitatama	Kodaira, Higashimurayama, Tanashi, Hoya, Higashiyamato, Kiyose, Higashikurume, Musashimurayama	Hagiyama
	612 Hachioji	Hachioji, Hino	Hachioji
	613 Minamitama	Machida, Tama, Inagi	Tama-Center
	614 Nishitama	Ome, Fussa, Akigawa, Nishitama County	Ome
	615 Islands	Oshima, Miyake, Hachijo & Ogasawara Branches	
7. Kanagawa	701 Yokohama Center	Tsurumi, Kanagawa, Nishi, Naka, Hodogaya	Yokohama
	702 Yokohama North	Kohoku, Midori	Shin'yokohama
	703 Yokohama South	Minami, Isogo, Kanazawa, Konan	Kamiooka
	704 Yokohama West	Totsuka, Asahi, Seya	Futamatagawa
	705 Kawasaki Coastal	Kawasaki, Saiwai, Nakahara	Shitte
	706 Kawasaki Tama	Takatsu, Tama	Noborito
	707 Miura	Yokosuka, Kamakura, Zushi, Miura, Hayama	Yokosuka, Itsumi
	708 Shonan	Hiratsuka, Fujisawa, Chigasaki, Samukawa, Naka County	Chigasaki
	709 Koza	Sagamihara, Yamato, Ebina, Zama, Ayase	Zama
	710 Atsugi	Hadano, Atsugi, Isehara	Isehara
	711 Odawara	Odawara, Minamiashigara, Nakai, Oi, Kaisei, Ashigarashimo County	Odawara
	712 Tsukui	Matsuda, Yamakita, Aiko & Tsukui Counties	Yamakita, Sagamiko

Note: Jurisdictions are as of Oct. 1980. When a county contains more than one township/village, and all of them belong to a single C-level zone, the name of county is listed instead of individual townships/villages.

sectors shown in Table 3.2. Since our model places emphasis on analyzing urban activities, a detailed classification is employed for services rather than material producing activities. In particular, Sector 18 (Clerical business) is considered separately from its mother industries to represent the managerial function which characterize the CBD. Corresponding to the spatial hierarchy, these sectors are classified into three categories; R, P and C-level goods or services. That is, the P-level and C-level goods are supposed to balance within a prefecture and a C-level zone, respectively, while the R-level goods are possibly traded across the regional border. For example, the government services are classified into three sectors, viz. national, prefectural and municipal, corresponding to the area over which each government has its jurisdiction.

Although Leontief[3] suggests to categorize the activities in accordance with the ordering based on net imbalances of their products, such an objective method seems impossible in our case. This is due to the fact that a number of sectors whose productions are defined as to coincide with the demands by each location when compiling the input-output table.†2

Table 3.2. Classification of industrial activities.

R 01	Agriculture, forestry and fisheries		N	J	P 19	Water supply	U	N	J
R 02	Mining		N	J	P 20	Residential building	U	N	
R 03	Food and beverages	U		J	P 21	Passenger transportation	U	N	J
R 04	Textile	U		J	P 22	Freight transportation	U	N	J
R 05	Wooden and paper products	U		J	P 23	Communication	U	N	J
R 06	Printing and publishing	U		J	P 24	Finance, insurance and real estate	U	N	J
R 07	Chemical products	U		J	P 25	Business services	U	N	J
R 08	Metal products	U		J	P 26	Entertainment	U	N	J
R 09	Machinery	U		J	P 27	Public works of P-level	U	N	
R 10	Other manufacturing	U		J	P 28	Community services of P-level	U	N	J
R 11	Electricity and gas	U	N	J	P 29	Government services of P-level	U		
R 12	Non-residential building	U	N	J					
R 13	Far-flung transportation	U	N	J	C 30	Retail	U	N	J
R 14	Wholesale	U	N	J	C 31	Personal services	U	N	J
R 15	Public works of R-level	U	N		C 32	Public works of C-level	U	N	
R 16	Community services of R-level	U	N	J	C 33	Community services of C-level	U	N	J
R 17	Government services of R-level	U			C 34	Government services of C-level	U		
R 18	Clerical business	U	N		C 35	Sewage and waste management	U	N	J

Notes: 1) R, P and C preceding the sector numbers represent that the sector is classified into R-level, P-level, and C-level activities, respectively.
2) Symbols U, N and J attached to sectors imply the following.
U = Urban activities whose employees are collectively called the urban employees,
N = Non-manufacturing private sectors used in conjunction with investments, and
J = Sectors whose net increase in stocks and net exports are possibly non-zero by definition.

†2. The sectors which are not marked with symbol J in Table 3.2. are those without net increase in stocks nor net export by definition.

Among them is the government services of R-level whose influence reaches the entire nation even though it can never be measured in monetary terms.

We employ the regional tables for Kanto Region published every five years by Japanese Ministry of International Trade and Industry (MITI) as to extract the fundamental input-output structures. However, it must be noted that the table is compiled for the extended Kanto Region which contains our Region and four other prefectures, Niigata, Yamanashi, Nagano, and Shizuoka. The statistical results in this study are based on the data collected between two consecutive census years, 1975 and 80, and the 11-prefectural input-output tables for these two years are shown in Appendix as Tables A.1 and A.2, respectively. From those tables, we can calculate the ratios in percentiles of imbalance to the production in the extended Region for the respective years. Table 3.3 shows the means and maxima of those ratios, as representatives for each level of commodities. From this we might infer that our categorization is acceptable in the sense that the goods or services of the lower levels are in general much more captive to the Region than when compared with those belonging to R-level.

3.2. General Construction of the Model[4]

The model is composed of the three major model blocks; the regional frame, the activity, and the location models, which are linked in a systematic way to form a recursive dynamic model as a whole. And each of them contains a number of submodels as Figure 3.1 indicates, whose outlines can be summarized as follows.

Table 3.3. The ratios of trade imbalance to production. $|FM_i|/X_i*100(\%)$, in 11 prefectures.

		R-goods	P-goods	C-goods	All goods
1975	Means	56.65	2.49	1.01	30.09
	Max.	781.39	7.54	4.58	
1980	Means	79.54	3.33	1.86	42.27
	Max.	1184.22	11.82	9.48	

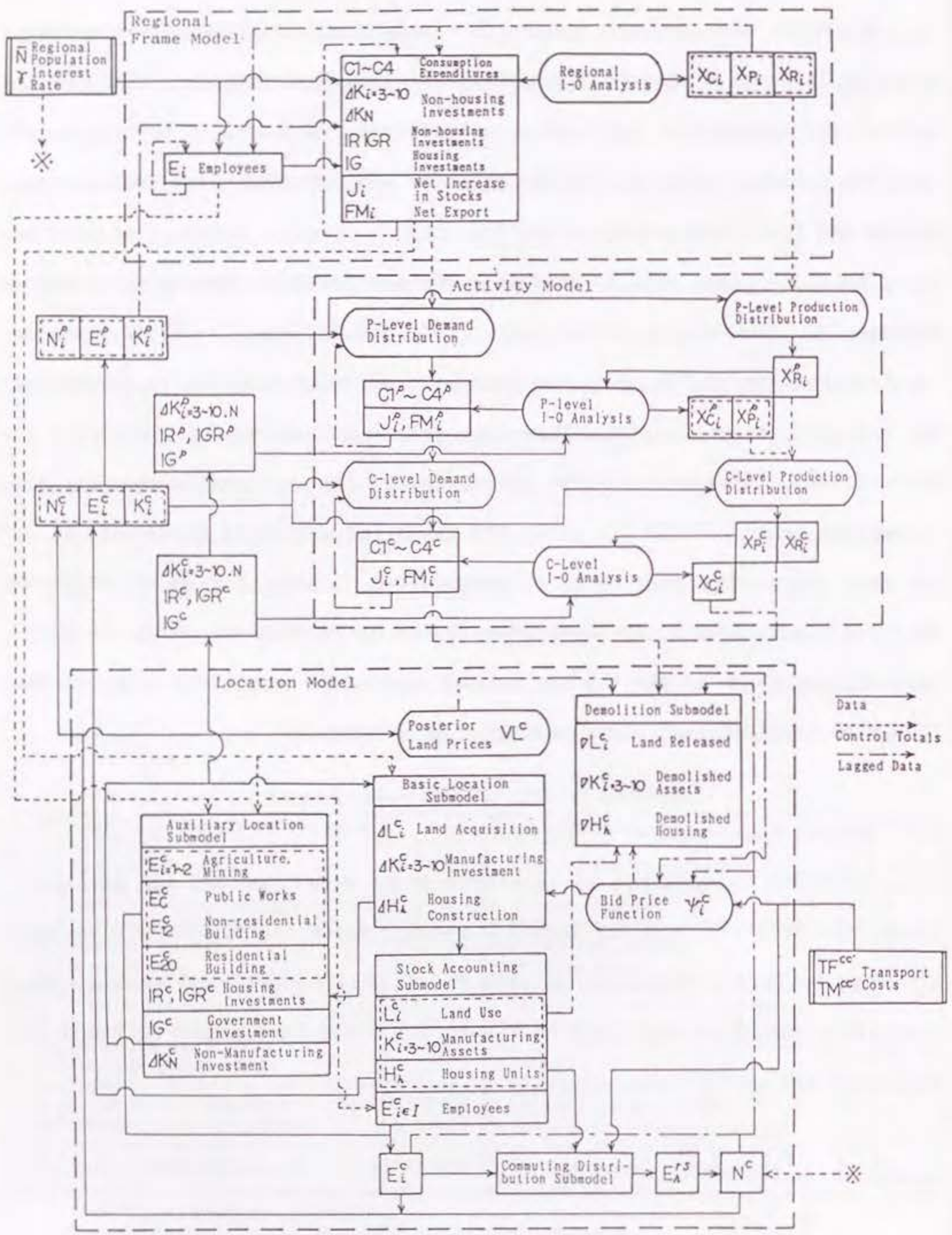

Figure 3.1. The general flow chart of the model.

The major exogenous variables to the model are the regional population N and the interest rate γ. Based on these and other predetermined variables obtained from the simulation steps for the previous years, the regional frame model is to determine regional macro statistics which serve as the control totals for various activities in the Region for the present period. The typical macro variables include the itemized final demands shown in Table 3.4, which can be classified into the following three categories.

i) consumption items; C1, C2, C3 and C4,

ii) investment items; IR, IF, IGR and IG, and

iii) balancing items; J and FM.

As the items in the third category are considered to fill in the gaps between demand and supply, those in the first two categories are collectively called the net final demand.

From those final demand items, the regional productions are calculated through the input-output analysis at the regional level. In addition, as our model essentially belongs the class of models called the distributive models, it is also necessary to determine the regional sums of locating indices, viz. the variables to be distributed over zones. The numbers of employees by sectors, E_i, and non-land capital investments in private sectors, ΔK_i (i=3, ...,10, and N for the non-manufacturing sectors), are such

Table 3.4. The final demand items.

01	C1	Consumption expenditures outside households	C	N
02	C2	Household consumption expenditures	C	N
03	C3	Central government consumption expenditures	C	N
04	C4	Local government consumption expenditures	C	N
05	IR	Private housing investment	I	N
06	IF	Private capital formation except housing	I	N
07	IGR	Government housing investment	I	N
08	IG	Government capital formation except housing	I	N
09	J	Net increase in stocks	B	
10	FM	Net export	B	

Note: Symbols C, I, B and N attached to items imply the following.
C = Consumption items, I = Investment items,
B = Balancing items, and
N = Items comprising the net final demand.

variables.

The activity model is aimed at estimating the zonal allocation of sectorial productions. The model combines the three level input-output (3LIO) model, which is essentially a three-stage version of Leontief's balanced input-output (BIO) model, with the distribution models for the itemized final demands and the productions. The ways to deal with the goods or services differ in response to the level to which they are classified.[5] The 3LIO model deviates from the BIO model by the fact that the final demands for all the commodities are distributed at a time, and this makes the net exports be obtained in the form of imbalances.[†3] It must be noted that the distributions of investment items need not be formulated in this model block as they are to be determined in accordance with their locations. Moreover, as the formulas for distributions of productions and consumption items depend on the location of employees, capital stocks, and other stock variables, the location model must precede the activity model in each simulation step.

The location model is composed of five submodels, viz. the basic location, stock accounting, auxiliary location, commuting distribution, and demolition submodels. It combines the results from the activity model for the previous period, such as the zonal productions and the zonal consumption expenditures with their own lagged results to distribute the regional employees and investments for the present period determined by the regional frame model. The fundamental tool in the model to deal with the locational competitions is the aggregate random bid prices, with which the available land area is assigned to the new locators in each zonal land submarket. To estimate removal of the present locators is another important function of the model, which precedes the location of activities to provide the arena

†3. The word net export refers to the total exports less imports of the area, where the balance equation is considered, with the rest of the world. Hence, when considering the imbalances at the local level, they include the domestic trading within the Region.

for the locational competitions. Accordingly, the stock variables including land areas allocated to each activity, numbers of housing units, and population by zones are also determined in this model block, and such outcomes provide information to the activity model for the present period.

Summarizing, the simulation proceeds in the manner that the location and activity models are repeated in each period under the regional frame model, which determines the control totals for the present economic activities. In this regard, the model incorporates the recursively dynamic procedures that the stock analyzing and the flow analyzing steps are executed alternately. While the detailed descriptions of those model blocks are given in Chapters 4 through 6, the rest of this chapter is devoted to discussions on some of the prerequisites which would become necessary in the course of the actual formulations and/or simulations.

3.3. Commodity Based Inflators[6]

When we attempt to simulate the economic activities during a certain period, it is common practice to describe all the monetary values in real terms, rather than nominal. In this connection, we employ the year 1975 as the base year for denominations. To achieve uniformity of prices, it is necessary to compute the price inflators for respective commodities. This section is aimed at describing a simple method to obtain such inflators using the input-output framework.

Commodity based inflators are published by Management and Coordination Agency as a part of the link input-output tables.[7] The inflators are available for the integrated sectorial classifications as well as for the basic classifications.[†4] However, as the way to integrate sectors differs from ours, it is not appropriate to use the former, and thus, rather

†4. The numbers of sectors fluctuate by years. The numbers of rows and columns, respectively, are 555 and 407 for 1970, 567 and 419 for 1975, 546 and 411 for 1980, and 529 and 408 for 1985.

complicated integration procedures would be required if we choose to use the latter information. Nevertheless, the resulted inflators are for the national level, which would not necessarily be applicable to our study area. Accordingly, we choose to calculate the commodity based inflators, which could be applicable to whatever sectorial classification, indirectly from the implicit deflators for the gross prefectural expenditures available in *Annual Report on Prefectural Accounts*.

The commodity based inflator $d_i = X_i^o/X_i$ (for the i-th commodity) can be calculated in the following manner. Suppose that the itemized final demands are given in both nominal (W_j) and real (W_j^o) terms (for the j-th item), where the superscript o indicates the real values throughout this section. The input coefficient in real terms can be written as

$$a_{ij}^o = X_{ij}^o/X_j^o = d_i X_{ij}/d_j X_j = (d_i/d_j)a_{ij}. \quad (3.1)$$

Using the input coefficient matrix A and the diagonal matrix D consisting of d_i's, $A^o = DAD^{-1}$ gives the matrix representation of eq.(3.1).

Meanwhile the itemized final demands are converted into the commodity based ones, Y_i, by means of the final demand converter, c_{ij}, which represents the proportion of the j-th item to be spent on the i-th commodity. That is, $c_{ij} = Y_{ij}/W_j$, where Y_{ij} denotes the nominal amount corresponding to c_{ij}, and thus, we have $Y = CW$ using the converter matrix C and the vector forms of Y_i and W_j. Similar to eq.(3.1), the final demand converter in real terms can be written as

$$c_{ij}^o = d_i Y_{ij}/\Sigma_i d_i Y_{ij} = d_i c_{ij}/\Sigma_i d_i c_{ij}. \quad (3.2)$$

This also becomes $C^o = DCE^{-1}$, using the diagonal matrix E whose j-th element is given by $\Sigma_i d_i c_{ij}$.

Now the nominal and real production vectors X and X^o, respectively, can be expressed by the following equations.

$$\text{(Nominal) } X = (I-A)^{-1}CW, \quad (3.3)$$

$$\text{(Real) } X^o = (I-DAD^{-1})^{-1}DCE^{-1}W^o. \quad (3.4)$$

Incidentally, from the definition of the inflator,

$$d_i = X_i^o/X_i \text{ or } D = (\text{diag } X_i^o)(\text{diag } X_i)^{-1}, \quad (3.5)$$

we can establish an iterative procedure to obtain d_i which satisfies eq.(3.4). That is, we first set the initial value of d_i to 1, and calculate the estimate of X^o from eq.(3.4). Then by comparing X^o with the nominal vector X, we revise the value of d_i by eq.(3.5) until the convergence criterion is met.

This method can produce a set of commodity based inflators which is consistent with the input-output matrix for the study area, and is applicable to the Region where such matrix and the nominal and real itemized final demands are available.†5 Although we attempt in the next section to modify the input-output tables for the extended Region to those consistent with our study area, we here compute the commodity based inflators using the 11 prefectural input structure as the modified tables would vary depending on the method of such modification. Table 3.5 summarizes the 1980 inflators for itemized final demands based on 1975 prices, and the resulted commodity

Table 3.5. The 1980 inflators for itemized final demands and commodities based on the 1975 prices.

Final demands		Commodity based inflators					
C1	-------	01	0.836610	13	0.870179	25	0.770336
C2	0.716710	02	0.605333	14	0.818757	26	0.699515
C3	0.750070	03	0.720891	15	0.708848	27	0.803826
C4	0.749893	04	0.664615	16	0.771234	28	0.677785
IR	0.718059	05	0.626454	17	0.764339	29	0.780155
IF	0.857090	06	0.890169	18	0.773250	30	0.674128
IGR	θ.722021	07	0.848820	19	0.708295	31	0.651358
IG	0.772615	08	0.872391	20	0.927274	32	0.708572
		09	0.712662	21	0.727128	33	0.637623
J	0.683714	10	0.822593	22	0.787684	34	0.780156
F	0.770638	11	0.727719	23	0.759503	35	0.750102
M	0.746189	12	0.831073	24	0.714555		

†5. It must be noted that there is a slight inconsistency concerning the periods on which the statistics are based. That is, while the itemized final demands are based on the fiscal year, the price indices with which the real terms are calculated, and the input-output tables are based on the calendar year. However, we disregard this conceptual difference so that we use the final demands as if they are calculated for the calendar year.

based inflators.[†6] As the convergence criterion, we employ $\varepsilon = \Sigma_i |d_i - d_i^{(-1)}| < 10^{-6}$, where the superscript (-1) indicates the values at the previous step. This criterion is met after 841 iterative steps in the present case.

Roughly speaking, what we seek through this method is to restore the commodity based price indices on which the final demand deflators should be based. It must be noted that while the inflators to be calculated here are of the Paasche type, the data they originate from, viz. the deflators in the income statistics, are of the Laspeyres type,[8)] and thus, there exists a slight conceptual discrepancy between them.

3.4. Nonsurvey Modification of Input Coefficients and Final Demand Converters

3.4.1. Nonsurvey method for regional input-output tables

As mentioned before, while our study area consists of 7 prefectures, the regional input-output tables to be used are compiled for 11 prefectures. It might be possible to apply the input structures shown in those tables directly to the Region, but it has been found inadequate to use them as they are. This stems from the fact that the imports in some sectors are too large to keep the total final demand positive. Consequently, the productions in such sectors could become negative, even though the Leontief inverse matrix is positive definite.[9)] And the fact that the positive productions are not guaranteed under input coefficients compiled for the extended Region suggests the necessity to modify those coefficients to meet the configuration of our Region.

†6. As the prefectural income statistics do not carry the consumption expenditures outside households C1, our calculation excludes this item. On the other hand, as the statistics carry exports F and imports M separately in most prefectures, we basically treat these items independently despite the problems of double countings associated with intra-regional trades. However, effects of such problems would be limited as we exclude trades to and from Tokyo and Kanagawa, where trades are listed collectively under the term of statistical discrepancy.

The existing studies on nonsurvey techniques are reviewed by Round[10)] and Richardson.[11)] In the spatial context, such studies might be classified into three categories, i.e., i) to obtain a subregional table from the regional one, ii) to obtain a multi-regional or interregional table for subregions, or iii) to apply the existing table to another but a similar region, out of which the first case applies to our circumstances. Typical studies have concluded with obtaining self-sufficiency rate (the proportion of i-th inputs provided domestically for producing a unit of j-th product) from the location quotients, and with little emphasis on the multi-regional consistencies. For example, Sasaki and Shibata[12)] try to construct a multi-regional input-output system using the regional export-to-production ratios, where the location quotient for subregion r is defined as an index to identify the degree of specialization to the i-th commodity.

$$l_i^r = (X_i^r/X^r)/(X_i/X)$$

In this case, cross trading is precluded although the sums of subregional trades are necessarily consistent with the regional ones.

On the other hand, the RAS method[13)] to reflect technical changes with time is widely applied in the spatial context. While this method requires intermediate demands and inputs to be known for the target region, it is practically impossible to obtain them independently for our Region. As the matter of fact, it is possible to estimate them using the input coefficients a_{ij} for the extended Region, but a_{ij} may never be modified in this case. In this connection, the following two points become the focus of the modification method to be proposed. That is, i) to determine the net export vectors in the subregions by explicitly considering cross trading, and ii) to modify the final demand converter matrix simultaneously with the input coefficients.

The former could be achieved by incorporating the inter-subregional trade model, and we here employ a simple gravity model, where no distance decay is expected, due to the limitation of trading data. The latter is to meet the minimal requirement of the RAS conversion that at least either of the intermediate sums is calculated independently of the original input structures. As we only need the output system of the input-output analysis in our model, the value added sectors are excluded from our modification method.[†7] Accordingly, our method combines the RAS conversion for the endogenous sectors with the Fratar method[14)] for the final demand sectors.

3.4.2. Net increase in stocks and net export

While the commodity compositions of the net final demand items are supposed to be relatively stable across regions, the net increase in stocks J_i^r and the net export $FM_i^r = F_i^r - M_i^r$ might drastically differ from the original compositions depending on the local supply and demand capabilities. In our context, the region refers to the 11 prefectural region which comprises two subregions, viz. our study area denoted by r and the remaining four prefectures denoted by s. And these two items need a separate consideration from those included in the net final demand.

Suppose that the increase in stocks arises at the production site, and there is no essential difference in demand-supply relationship across regions. Then we could employ the following approximation.[15)]

Assumption 3.1. The regional net increase in stocks J_i is distributed over subregions in proportion to the local productions, i.e.,

$$J_i^r = (X_i^r/X_i)J_i. \tag{3.6}$$

Regarding the net exports, we make the following assumption, where we call the trading to and from outside the region export F and import M, respectively, to distinguish them from the intra-regional trade T^{rs}.

Assumption 3.2. i) The export is distributed over subregions in proportion to the local productions, and the import is proportional to the local net

†7. It is possible to apply the RAS method simultaneously to the final demand and value added sectors by means of a closed system (see Jensen and McGaurr[20)]).

demands. ii) The regional supplies of the commodities are distributed over subregions in proportion to the local net demands.

The net demand is defined as the sum of the intermediate and the net final demands. In subregion r, for example, it is given as follows.

$$D_i^r = \Sigma_{j=1}^{35} a_{ij} X_j^r + \Sigma_{j=1}^{8} c_{ij} W_j^r \tag{3.7}$$

Then the above assumption can be written in the following manner.

$$\text{i) } F_i^r = (X_i^r/X_i)F_i, \quad M_i^r = (D_i^r/D_i)M_i, \tag{3.8}$$

$$\text{ii) } T_i^{rs} = (D_i^s/D_i)(X_i^r - F_i^r), \tag{3.9}$$

where the latter expression represents a simple gravity model which is consistent w.r.t. spatial aggregations.

Figure 3.2 depicts the trades associated with our extended Region. The net export of the i-th commodity in our study area can then be decomposed as follows.

$$FM_i^r = (F_i^r + T_i^{rs}) - (M_i^r + T_i^{sr}) \tag{3.10}$$

The subregional converters for the balancing items can be calculated in accordance with eqs.(3.6) and (3.10).

$$c_{i9}^r = J_i^r/\Sigma_i J_i^r, \quad c_{i,10}^r = FM_i^r/\Sigma_i FM_i^r \tag{3.11}$$

It must be noted that these two items may take either positive or negative values, and thus, the denominators of eq.(3.11) may possibly become zero. In that case, it would become necessary to distinguish between the positive

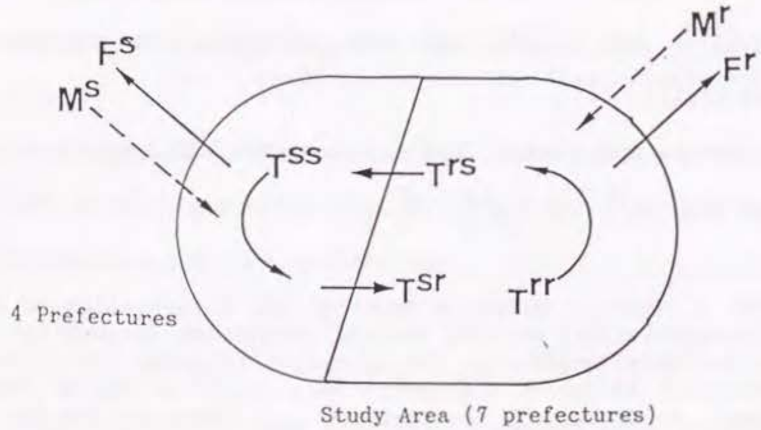

Figure 3.2. The trades associated with the extended Region.

and negative values in calculating the converters to avoid indefinite results.

3.4.3. Input coefficients and net final demand items

The modification of the converters corresponding to the net increase in stocks and the net export is proved to be insufficient in explaining the subregional economic structures. Hence, it is necessary to modify the rest of the coefficients to meet the configuration of our study area. Incidentally, the fact that the 7 prefectural region is economically dominating in most respects in the extended Region suggests the applicability of mechanical modification techniques. Hence, we propose a method based on the RAS and Fratar methods as described below, whose procedures are also shown in Figure 3.3 as a flow chart.

i) Set the step number k at 0. Calculate the initial value of the final demand for the i-th commodity from the j-th item, $Y_{ij}^{(0)}$, using the converters for the extended Region, c_{ij}, and then, that for the commodity based net final demand,†8 i.e.,

$$Y_{ij}^{(0)} = c_{ij} W_j^r \quad \text{and} \quad Y_i^{(0)} = \Sigma_j Y_{ij}^{(0)}.$$

We also calculate the initial value of intermediate input using the input coefficients, $a_{ij}^{(0)} = a_{ij}$, for the extended Region; $Z_j^r = \Sigma_i a_{ij} X_j^r$.

ii) Calculate the net increase in stocks and the net export for the study area using eqs.(3.6) and (3.10), and then calculate the corresponding converters by eq.(3.11).

iii) Let k be the new step number, and calculate the intermediate demand for the previous step; $U_i^{(k-1)} = \Sigma_j a_{ij}^{(k-1)} X_j^r$.

†8. In practice, a negative value is found at the intersection of Sector 13 (Far-flung transportation) and the central government consumption C3 in the 1980 table, probably because of the subsidies to cover the deficit of the Japanese National Railways. Although this negative figure requires separate treatment, we discuss in the text the case where all the net final demands are positive. This is due to the fact that the negative figure can be regarded as a peculiar case. For an example of such treatment, refer to Ando and Sakai.[6]

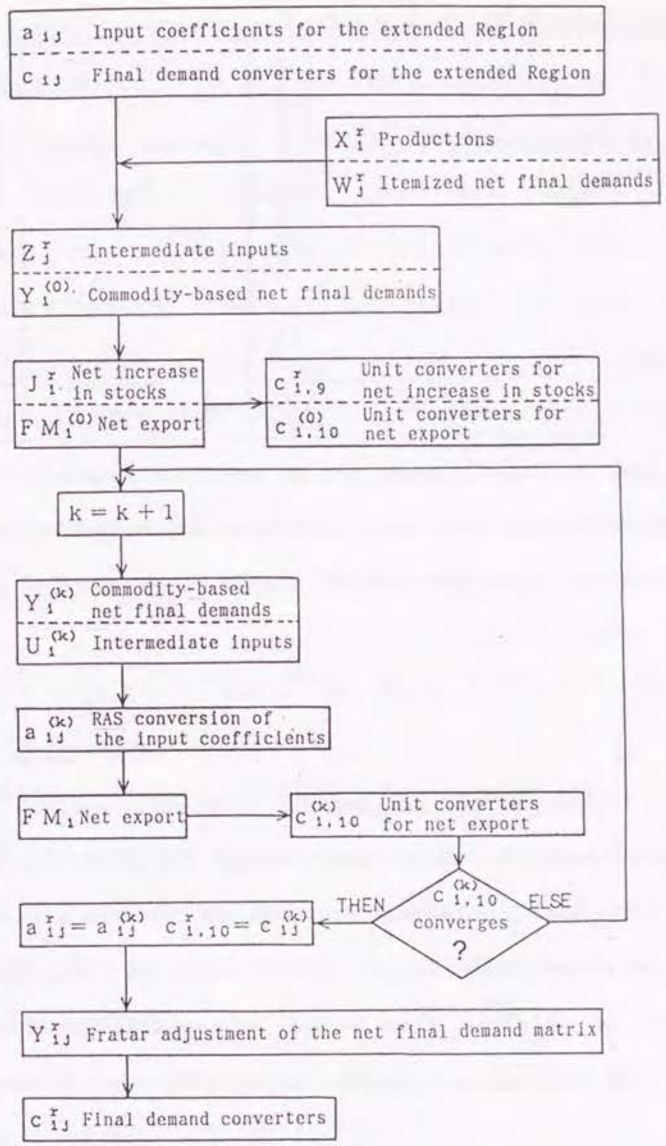

Figure 3.3. The flow chart of the process which jointly modifies input coefficients and the final demand converters.

As we can observe from Figure 3.4, which illustrates an input-output table, that there exist alternative ways to obtain the commodity based net final demand as well as the intermediate one.

$$Y_i^{(k-1)'} = X_i^r - J_i^r - FM_i^{(k-1)} - U_i^{(k-1)}, \tag{3.12}$$

$$U_i^{(k-1)'} = X_i^r - J_i^r - FM_i^{(k-1)} - Y_i^{(k-1)}, \tag{3.13}$$

Since these values and those previously obtained have to coincide with each other pairwise, we try to narrow down the discrepancies by taking averages

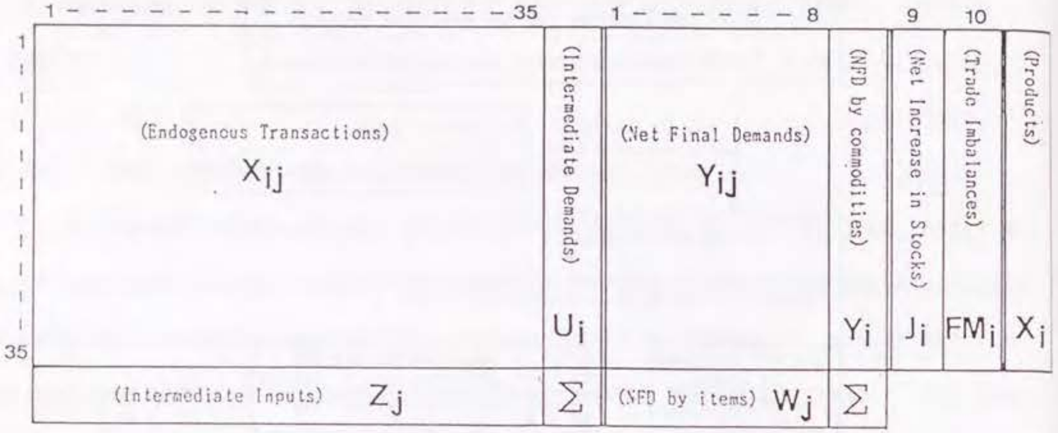

Figure 3.4. An illustration of an input-output table.

of the two separate estimations. And let the values of these averages which are adjusted to meet the control totals, $\Sigma_j W_j^r$ and $\Sigma_j Z_j^r$, be the estimation at the present step, i.e.,

$$Y_i^{(k)} = (Y_i^{(k-1)''}/\Sigma_i Y_i^{(k-1)''})\Sigma_j W_j^r, \quad U_i^{(k)} = (U_i^{(k-1)''}/\Sigma_i U_i^{(k-1)''})\Sigma_j Z_j^r, \qquad (3.14)$$

where

$$Y_i^{(k-1)''} = (Y_i^{(k-1)} + Y_i^{(k-1)'})/2 \text{ and } U_i^{(k-1)''} = (U_i^{(k-1)} + U_i^{(k-1)'})/2. \qquad (3.15)$$

However, in sectors either whose final demands are zero by definition, viz. 18 (Clerical business), or whose intermediate demands are zero, viz. 20 (Residential building) and the government services (17, 29, 34, only in 1975), the values obtained from either of eq.(3.15) should eventually become zero. In this connection, we use the alternate formulas for these sectors, i.e., $U_i^{(k-1)''} = U_i^{(k-1)} + Y_i^{(k-1)'}/2$ for sectors in the former category, and $Y_i^{(k-1)''} = Y_i^{(k-1)} + U_i^{(k-1)'}/2$ in the latter.

iv) Apply the RAS method to the endogenous sectors to modify the input coefficients $a_{ij}^{(k-1)}$ of the previous step. The revised coefficients $a_{ij}^{(k)}$ are in conformity with the row sums $U_i^{(k)}$ and the column sums Z_j^r.

v) Calculate the regional net demand by $D_i^{(k)} = \Sigma_j a_{ij}^{(k)} X_j^r + Y_i^{(k)}$. From this, we can estimate the net export for the present step, $FM_i^{(k)}$, using eqs.(3.8) through (3.10).

vi) Check with the convergence criterion. If it is satisfied, proceed to the concluding process vii), or otherwise return to step iii).

vii) Apply the Fratar adjustment to the net final demand sectors using the row and column sums, $Y_i^{(k)}$ and W_j^r, and the initial net final demand matrix, $\{Y_{ij}^{(0)}\}$, as the present pattern. From the resulting matrix, $\{Y_{ij}^{(k)}\}$, we can calculate the converters for the net final demand items, $c_{ij}^{(k)}$, i=1,..., 8.

Our method could be applied to the target areas wherever the productions by sectors and the itemized final demands are known. As mentioned before, it concentrates on the output system, the revisions are made only along the row direction, and thus, the column sums, Z_j^r and W_j^r, are fixed at the initial values. Although it is possible to extend our method to incorporate modifications along the column direction, the present method is proved to be sufficiently effective according to the empirical results shown below.

3.4.4. Empirical results

We have applied our method to the 1975 and 80 tables compiled for the extended Region to meet the configuration of our study area. Such modifications are made on the nominal basis, and thus, the conversions to the real basis are made after the convergence criterion is met. The convergence criterion employed is $\varepsilon = \Sigma_i |c_{i,10}^{(k)} - c_{i,10}^{(k-1)}|/35 < 10^{-9}$, which is satisfied after 21 and 16 steps of iterations for the 1975 and 80 tables, respectively.

For examining the effects of modifications, we consider the following three cases; (a) the case using the input coefficient and the final demand converter matrices, including those for the net increase in stocks J and the net export FM, obtained from the original tables, (b) the case similar to case (a), but modifying the converters for J and FM, and (c) the case revising the entire matrices through the procedures described in the previous subsections.

Table 3.6 summarizes the converters for the net export corresponding to these three cases. While the converters in cases (a) and (b), in

Table 3.6. The converters for the net export and r_i and s_j for the endogenous sectors.

	(a-75)	(b-75)	(c-75)	(a-80)	(b-80)	(c-80)	r_i(75)	s_j(75)	r_i(80)	s_j(80)
01	-1.1198	-1.1391	-0.1346	-1.2578	-1.2828	-0.1099	0.1870	2.1532	0.1467	2.6981
02	-1.8980	-1.4391	-0.0721	-2.7065	-2.0746	-0.0193	0.0032	17.991	0.0006	29.034
03	-0.3234	-0.7397	-0.0566	-0.5176	-0.9428	-0.0415	1.4864	1.2147	1.1186	1.6107
04	-0.4175	-0.5266	-0.0481	-0.5439	-0.5960	-0.0285	0.2419	3.8649	0.1159	7.2692
05	-0.5817	-0.7851	-0.0877	-0.7018	-0.9327	-0.0461	0.1599	3.2715	0.0956	4.8457
06	0.3174	0.5119	0.1006	0.5357	0.8519	0.0874	0.3083	3.8072	0.3477	3.4871
07	0.6253	0.0273	0.1163	0.6817	-0.2668	0.0594	0.5256	1.6845	0.5765	1.5979
08	-0.0539	-0.8704	-0.0062	-0.5092	-1.4364	-0.0356	0.5099	1.2804	0.5405	1.1296
09	3.1113	3.5866	0.8617	5.1272	5.7500	0.7358	4.0903	0.3427	3.9529	0.3489
10	0.1305	0.5783	0.0414	-0.0062	0.2550	0.0010	0.4730	2.0194	0.4134	1.9617
11	-0.1213	-0.0845	-0.0278	-0.3871	-0.3056	-0.0422	0.1900	3.8809	0.1960	4.5943
12	0.0005	0.0825	0.0001	-0.0059	0.0594	-0.0008	2.4895	2.1100	1.6955	2.1769
13	0.2914	0.3226	0.0526	0.1071	0.1986	0.0108	0.4443	1.7567	0.3360	2.1322
14	0.6830	0.7430	0.1620	0.9676	1.0758	0.1145	1.0422	0.8923	0.9910	0.7805
15	---	--	---	---	--	---	1.6727	21.125	1.4158	20.667
16	0.0049	0.0100	0.0013	0.0405	0.0529	0.0055	0.2703	4.7990	0.6138	2.9366
17	---	--	---	---	--	---	1.	5.3251	13.741	7.0114
18	---	--	---	---	--	---	0.5901	1.	0.5816	1.
19	0.0001	-0.0004	0.0000	-0.0004	0.0002	-0.0001	0.0316	13.402	0.0292	17.669
20	---	--	---	---	--	---	1.	2.1809	1.	2.3507
21	0.0276	0.1205	0.0075	0.0445	0.1196	0.0061	0.7069	2.5394	0.4744	3.8318
22	0.0922	0.1577	0.0252	0.1366	0.1771	0.0192	0.2002	3.8908	0.1321	5.2358
23	0.0130	0.0502	0.0035	0.0300	0.0833	0.0042	0.1745	5.0412	0.1689	4.2568
24	0.3625	0.3912	0.0950	0.2282	0.2863	0.0310	1.8278	0.1882	2.0849	0.2947
25	0.0906	0.0478	0.0232	0.2448	0.2216	0.0328	0.3966	1.0113	0.5032	0.9355
26	0.0095	0.0120	0.0025	0.0140	0.0097	0.0019	0.9875	2.2640	0.6349	3.2437
27	---	--	---	---	--	---	156.68	3.3285	106.07	4.7546
28	-0.0872	-0.0622	-0.0212	-0.1598	-0.1336	-0.0188	0.6678	4.1750	0.3274	5.0791
29	---	--	---	---	--	---	1.	4.4493	2.3854	5.2140
30	-0.0188	0.0916	-0.0050	-0.0186	0.1098	-0.0024	1.7988	1.3332	1.5800	1.3566
31	-0.1201	-0.0852	-0.0287	-0.3149	-0.2769	-0.0350	17.189	1.2411	14.113	1.5894
32	---	--	---	---	--	---	4.2845	14.868	3.9685	14.686
33	-0.0180	-0.0033	-0.0046	-0.0274	-0.0062	-0.0036	11.944	1.4478	9.3100	2.0889
34	---	--	---	---	--	---	1.	6.0077	1.8860	6.5949
35	0.0000	0.0025	0.0000	-0.0006	0.0032	-0.0001	0.0894	17.893	0.0765	15.273

Note: Column (a) lists the converters for the net export in the original table compiled for the extended Region. Column (b) corresponds to the partial conversions where only the net increase in stocks and the net export are recalculated by the procedures described in 3.4.2. Column (c) corresponds to the results of full conversions as described in 3.4.3.

general, are of the similar order, those in case (c) tend to show smaller values. Although this does not necessarily mean that either exports or imports are under-estimated in that case, a significant portion of the imbalances are transferred to the net demand sectors as the consequence of modifications. This could be explained as follows. While the procedures in 3.4.3 for the net demand sectors are designed to revise coefficients so as to reproduce the economic configurations of the target area, those in 3.4.2 for the net export are based on a simple gravity model, which may be far from reality. Thus when both procedures are linked, the magnitude of transactions would shift to the sectors governed by the former, which would be more realistic.

Table 3.6 also lists the results of the RAS conversion in case (c). According to Stone[16)], the coefficients premultiplied r_i and postmultiplied s_j represent the substitution and fabrication effects, respectively.[†9] The sectors with low intensity in terms of intermediate demands tend to be compensated by high intensity in terms of intermediate inputs. Sectors 02, 04, 05, 11, 19, 22, 23, 28 and 35 belong to this category. They are either industries which are not characteristic to the urbanized areas, such as mining and light industries, or utilities which must be operated despite the high costs associated with such areas. On the other hand, among the generally low values of the substitution multipliers, products of sectors 09, 12, 24, 31, and 33 are heavily demanded in the Region. Those sectors are either necessary to support businesses or people who are engaged in them. Incidentally, the fact that the magnitudes of multipliers associated with the public works are unstable depending on the levels would be resulted from relatively small input coefficients along their rows, and the difference between substitution multipliers for the government services in 1975 and 80 reflect the definitional changes in their production.

Figure 3.5 summarizes the productions obtained as the results of input-output calculations,

$$\hat{X}^r = (I-A)^{-1}(CW^r+J^r+FM^r), \qquad (3.16)$$

based on the itemized final demands in the Region, corresponding to the three cases along with the observed ones. As we pointed out its possibility earlier, the negative production is resulted in 1975 for Sector 02 (Mining) when using the original coefficients. In 1980, no negative

†9. The sectors with r_i=1 reflect the fact that the intermediate demands to their outputs are zero, and those with s_j=1 that the intermediate inputs demanded by them are zero, by definition. r_i is said to represent the degree of intensity to the i-th output in terms of intermediate demands, while s_j is that of the value added in the j-th sector, in the target area. However, as the value added ratios are fixed in our method, the latter must be understood as to represent the intensity in terms of intermediate inputs by the j-th sector, as compared to the other sectors.

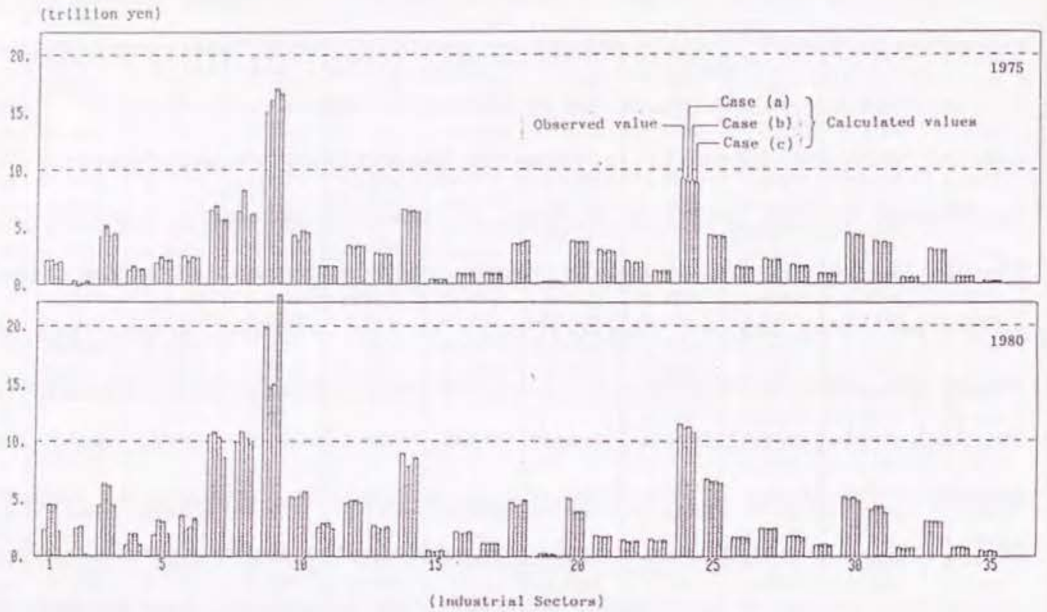

Figure 3.5. The calculated values of sectorial productions for 1975 and 1980.

results are obtained, but the predictions in cases (a) and (b) are associated with large errors especially in Sectors 01 and 09, besides 02 whose predicted value reaches 10 times as large as the observed. We can also observe that our modification method in case (c) works selectively in improving the predictions of those sectors with large errors.

Finally to see the general performances of respective cases, we calculate the root mean squared errors (RMSE) and the mean absolute percentage errors (MAPE) defined by the following formulas.

$$\text{RMSE} = \sqrt{\Sigma_i (\hat{X}_i^r - X_i^r)^2/35} \quad \text{and} \quad \text{MAPE} = (100/35)\Sigma_i |\hat{X}_i^r - X_i^r|/X_i^r .$$

From Table 3.7, we can observe that case (c) exhibits major improvements over case (a) in both years. However, case (b) turns out in mixed results, i.e., although the modification of converters for J and FM alone is fairly

Table 3.7. The error statistics for the calculated values of productions (RMSE are in million yen).

	1975		1980	
	RMSE	MAPE	RMSE	MAPE
CASE (a)	446774	12.01%	1172504	44.56%
CASE (b)	398841	5.20	1098430	45.24
CASE (c)	328975	4.35	644020	5.59

effective in 1975, essentially it brings about no improvement in 1980. The reason for this would be explained by the fact that the total imbalance in the 7 prefectural region has decreased from 1668 billion yen in 1975 to a quarter level, 430 billion in 1980. Consequently, the modification to the net export constitutes only small fractions of productions in 1980.

3.5. Model Parameters and Spatial Levels

3.5.1. Relevance of transferring parameters

The operational model to be formulated in the following chapters includes many parameters, which must be estimated from the observed data. Each model formula corresponds to some spatial level, but many of them are expected to predict the common variable at different spatial levels. For example, the regional frame and the activity models have equations to predict the regional household consumption expenditures C2 and their spatial distributions, $C2^p$ for prefecture p and $C2^c$ for zone c, respectively. In such a case, it would be inconsistent to use entirely different formulas against the different spatial levels. As our study period, for which the data are collected, contains six consecutive years, normally we would have only five observations at the regional level, if the equation contains a first-order lagged variable. Hence, it would be necessary to use the pooling data concerning prefectures over the years to maintain a sufficient degree of freedom, even when estimating parameters for the formula to predict the regional variables. On the other hand, as data in C-level zones are not immunized from compilation errors, it would be practical to estimate most of the parameters at the prefectural level, irrespective of the spatial level of the variables to be predicted. In this connection, it is meaningful to examine the possibility of transferring parameters to the formulas for a different level.[17)]

3.5.2. Linear expressions

The problem associated with such transfers essentially related to the treatment of intercepts as far as the model formulas are linear. However, such a problem can easily be resolved as the following illustration indicates. We here discuss the case when we apply the parameters estimated at the prefectural level to the formula for the regional level.

Suppose the regional formula is given by

$$Y = \alpha_0 + \Sigma_j \alpha_j X_j, \tag{3.17}$$

and the parameters are estimated from its prefectural counterpart,

$$Y^p = \beta_0 + \Sigma_j \beta_j X_j^p. \tag{3.18}$$

Then if we denote the estimators by hats, from the unbiasedness of eq. (3.18), we have

$$\Sigma_p Y^p = \hat{\beta}_0 n + \Sigma_j \hat{\beta}_j \Sigma_p X_j^p, \tag{3.19}$$

where n is the number of prefectures.†10 However, this gives nothing but an estimation of eq.(3.17) as $\Sigma_p Y^p = Y$ and $\Sigma_p X_j^p = X_j$ from the aggregative relations. That is, the parameters at the regional level are the same as the prefectural ones except for the intercept, which must be multiplied by the number of prefectures, viz. $\hat{\alpha}_0 = \hat{\beta}_0 n$ and $\hat{\alpha}_j = \hat{\beta}_j$. On the contrary, when applying the prefectural parameters to C-level zones, the intercept must be divided by the number of zones belonging to each prefecture.

However, as we discuss later in Sections 4.2 and 5.4, we might utilize the "standard values" to avoid the problems associated with the intercepts. Suppose the standard value for each variable at the regional level is given to the model, possibly from a macro-econometric model, and the superscript o denotes such variables. Then by taking the Taylor expansion around those standard values, eq.(3.17) becomes as follows.

†10. This expression refers to the single year computations. When data are pooled over several years, there is no guarantee that eq.(3.19) is satisfied every year unless the dummy variables to represent the years are introduced. However, when there are no particular chronological trends regarding such dummy variables, the condition will be satisfied asymptotically.

$$Y = Y^o + \Sigma_j \alpha_j (X_j - X_j^o) \tag{3.17)'}$$

In case applying to C-level zones, we might employ the prefectural values, divided by the number of zones in the prefecture, as the standard values.

Another way to avoid the problem is to "standardize" the equation by removing the effect of zone sizes. For example, the midterm macro-econometric model of Japan[18] explains the household consumption expenditures C2 by means of a simple Keynesian model where the present disposable income and the consumption in the previous period, as an inertial term, are used. In our notation, this can be written as

$$C2 = \alpha_0 + \alpha_1 C2_{-1} + \alpha_2 VA, \tag{3.20}$$

where the value added VA replaces the personal income.†11 Transforming this equation to the per capita basis,

$$C2/N = \beta_0 + \beta_1 (C2_{-1}/N) + \beta_2 (VA/N), \tag{3.21}$$

we could have an expression whose intercept β_0 is independent of scale diversifications. In this case, the parameters $\hat{\beta}_j$ could be estimated on the per capita basis at the prefectural level. The actual prediction of C2, on the other hand, is obtained by multiplying N to eq.(3.21) using these parameters, viz. from

$$\hat{C2} = \hat{\beta}_0 N + \hat{\beta}_1 C2_{-1} + \hat{\beta}_2 VA. \tag{3.20)'}$$

In applying parameters to the different spatial level, we must face another type of problems concerning the completeness of variables in terms of spatial units. That is, when we consider the small zones, the phenomena of transfers or spillovers beyond the zones could not be overlooked. We shall return to this problem later in Section 4.2.

3.5.3. Log-linear expressions

We have seen that the parameters for the linear expressions are transferable to a different spatial level. However, when the expression is

†11. It is consistent with the input-output framework to assume that a certain portion of the value added is allocated to the personal income.

nonlinear, such transferability could not be expected in general. Nevertheless, for the log-linear expressions, we can establish the property as far as the model is distributive.

Suppose the prefectural production is given by a log-linear formula;

$$\ln X^p = \beta_0 + \beta_1 \ln K^p + \beta_2 \ln E^p, \tag{3.22}$$

and a prefecture p contains n zones, one of which is characterized by the combination of (X^c, K^c, E^c). Then the Taylor expansion of $\ln X^c$ around $\bar{X} = X^p/n = \Sigma_{c \in p} X^c/n$ and alike, up to the quadratic term, will be as follows.

$$\begin{aligned}\ln X^c = {} & \beta_0 + (X^c - \bar{X})/\bar{X} - (X^c - \bar{X})^2/2\bar{X}^2 - (1-\beta_1-\beta_2)\ln n \\ & + \beta_1[\ln K^c - (K^c - \bar{K})/\bar{K} + (K^c - \bar{K})^2/2\bar{K}^2] + \beta_2[\ln E^c - (E^c - \bar{E})/\bar{E} + (E^c - \bar{E})^2/2\bar{E}^2]\end{aligned} \tag{3.23}$$

If $\ln X^p$ follows the normal distribution $N(\mu, \sigma^2)$, X^p follows a log-normal distribution with the mean and variance of $(\lambda_X = e^{\mu+\sigma^2/2}, \zeta_X = e^{2\mu}(e^{2\sigma^2} - e^{\sigma^2}))$.[19] Accordingly, if each X^c is independently and identically distributed, its mean and variance will be $(\lambda_X/n, \zeta_X^2/n)$, and the ones for $\bar{X}$ will be given by $(\lambda_X/n, \zeta_X^2/n^2)$. Likewise we assume the means and variances for K and E at the prefectural level are given respectively by (λ_K, ζ_K^2) and (λ_E, ζ_E^2).

By taking expectations over the moment terms in eq.(3.23), and regarding β_0, β_1 and β_2 as the set of true parameters for eq.(3.22), the estimate for $\ln X^c$ will be given by the following expression.

$$\begin{aligned}\ln \hat{X}^c = {} & \beta_0 - (1-\beta_1-\beta_2)\ln n - (n-1)\zeta_X^2/2\lambda_X^2 \\ & + \beta_1(\ln K^c + (n-1)\zeta_K^2/2\lambda_K^2) + \beta_2(\ln E^c + (n-1)\zeta_E^2/2\lambda_E^2)\end{aligned} \tag{3.24}$$

The adjustment terms in eq.(3.24) are to correct the associated aggregation biases when applying parameters estimated for the different regional level. However, even if the adjustment terms are incorporated, the estimated values $\hat{X}^c = \exp(\ln \hat{X}^c)$ do not necessarily satisfy the aggregative consistency; $\Sigma_{c \in p} \hat{X}^c = X^p$. It is a common practice to employ the distributive formula where the estimates for the lower level are used only to determine the proportions, viz. $X^c = (\hat{X}^c / \Sigma_{c \in p} \hat{X}^c) X^p$. As the adjustment terms become a simple multiplicative when an exponent is taken, they are canceled out in such cases. Thus it is possible to use the expression $\hat{X}^c = e^{\beta_0}(K^c)^{\beta_1}(E^c)^{\beta_2}$ with the parameters estimated for the prefectural level to determine the proportions by which the prefectural production is to be distributed.

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CHAPTER 4

THE ACTIVITY MODEL

In this chapter, we formulate the model block to analyze the spatial allocations of flow variables concerning the metropolitan activities. The mainstream of the analysis is based on the three level input-output (3LIO) model, which must be accompanied by the supplementary distribution models for productions and consumption items. The trades are analyzed in the form of demand-supply imbalances, which are determined from the balance equations. As some consumption items depend on the concurrent productions, the procedures to determine them simultaneously are also discussed.[1)]

4.1. The Three-Level Input-Output Model

The main framework of the activity model is provided by the 3LIO model, which is essentially a three stage rendition of the BIO model[2)] corresponding to the hierarchical classification of activities defined in Section 3.1.[†1] While the input-output analysis can easily be incorporated into a macro-econometric model, its applications are mostly limited either to the national level or to the regions comparable to our study area with a few exceptions.[3)] Some metropolitan models also utilize the input-output scheme within the model, but mainly to determine the regional macro values.[4)] In this connection, the activity model to be described here is unique in the sense that it applies the scheme to the zonal level composing the Region by virtue of the BIO framework.

Although the 3LIO model constitutes a major portion of the activity model, it is convenient to consider that the R-level computations of the

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†1. As Leontief's original model considers three stages, viz. the nation, the regions, and the subregions, the framework with three stages is nothing new. However, the most important difference with our model is in the way by which we treat intra-regional trades. In particular, while his model essentially does not predict the spatial allocations of consumptions for the goods classified to the highest level, we consider the allocations for all the commodities at a time.

3LIO model are executed as a part of the regional frame model to be discussed in the next chapter. From the viewpoint of the simulation procedures, the results from the R-level computations would provide the control totals to the computations for the two lower levels in the 3LIO model, which constitute a part of the activity model. As these computations assume the spatial allocations of stock variables to be predetermined, the execution of the location model must precede the activity model.

To operate an input-output analysis, the final demand data are indispensable. In our case, they are available by prefectures from *Annual Report on Prefectural Accounts*, but only in the form of the itemized expenditures, shown in Table 3.4. Hence, it is necessary to convert them into the commodity based ones using the final demand converters, c_{ij}, which are commonly used in the national macro-econometric models.[5)] However, such conversion is only possible for the first eight items, collectively called the net final demand items, as the commodity composition of the balancing items are not stable across the localities nor with time. Accordingly, when we denote the vectors of the net final demand items and the commodity based final demands by W and $\tilde{Y}$ respectively, we can write

$$\tilde{Y} = CW = C[C1\ C2\ C3\ C4\ IR\ IF\ IGR\ IG], \tag{4.1}$$

where C is a (35 x 8) matrix of converters corresponding to the net final demand items.

The model framework is similar to the one developed by a research group including the author,[6)] where the following assumptions are employed in addition to the regular input-output assumptions.

Assumption 4.1. The same input and final demand structures apply throughout the study area. That is, the input coefficient and final demand converter matrices, $A=[a_{ij}]$ and $C=[c_{ij}]$, are invariant across the localities within the Region.

In the above, the word "localities" refers to zones irrespective of the spatial level. The following assumption recapitulates the discussion

in Section 3.1 on the definition of levels.

Assumption 4.2. Hierarchy of activities is defined in three levels. Accordingly, there will be no inter-prefectural trades for P-level goods, and no inter-zonal trades for C-level goods.

In other words, while there is no restriction on trades of R-commodities, P-level goods are allowed to trade within the P-level zone they are produced. And zonal autarky is assumed for C-level goods. It must be noted that the actual observation includes some amount of exports and imports, F and M, inherited from outside the Region,[†2] despite the fact that the BIO assumption precludes the trading of local commodities. Thus it is necessary to distribute the extra-regional trades over lower level zones to maintain the consistency of the input-output calculations. In our model, the trades are considered in a combined form, viz. FM = F-M called the net export.

Assumption 4.3. The net exports of local commodities with outside the Region are to be distributed over localities in proportion to local productions.

Let subscripts R, P, C and L denote the partition of vectors corresponding to R-level, P-level, C-level goods and non R-level (local) goods, respectively. We further assume that superscripts p and c represent the variables in prefecture p and zone c, respectively.[†3] Then denoting the (regional) production vector by X, the above assumption implies the following.

$$FM_L^p = (\mathrm{diag}\ X_L^p)(\mathrm{diag}\ X_L)^{-1}FM_L \quad \text{and} \quad FM_C^c = (\mathrm{diag}\ X_C^c)(\mathrm{diag}\ X_C^p)^{-1}FM_C^p \tag{4.2}$$

A similar argument is also assumed for the net increase in stocks.

Assumption 4.4. The net increase in stocks J is distributed over zones in

†2. The words exports and imports refer to those to and from outside the Region and thus including domestic trades between the other parts of the nation as well as the overseas ones.

†3. We alternately use superscript d to indicate variables in zone d of the unspecified level. The variables without superscript are generally used to indicate regional values.

proportion to productions, i.e.,

$$J^{d} = (\mathrm{diag}\ X^{d})(\mathrm{diag}\ X)^{-1}J \qquad (4.3)$$

The balance equation for the Region is then given as follows.

$$\begin{vmatrix} X_R \\ X_P \\ X_C \end{vmatrix} = \begin{vmatrix} A_{RR} & A_{RP} & A_{RC} \\ A_{PR} & A_{PP} & A_{PC} \\ A_{CR} & A_{CP} & A_{CC} \end{vmatrix} \begin{vmatrix} X_R \\ X_P \\ X_C \end{vmatrix} + \begin{vmatrix} \tilde{Y}_R+J_R+FM_R \\ \tilde{Y}_P+J_P+FM_P \\ \tilde{Y}_C+J_C+FM_C \end{vmatrix} \qquad (4.4)$$

When the regional final demand vectors, $\tilde{Y}$, J and FM, which are to be determined in the regional frame model, are given, the regional production vector X can be calculated from the above equation.

In our model, the commodity compositions of final demands are calculated after distributing the itemized ones over the localities. This implies that the local final demands for all sectors are calculated at a time while the BIO model only requires local distribution of final demands for local goods. Accordingly, our framework must be supplied with the distribution models for the final demand items as well as for a part of the productions as prescribed by the original balanced model. Details of those distribution models will be discussed in Sections 4.2 and 4.3.

The balance equation for the P-level computation becomes

$$\begin{vmatrix} X_P^P \\ X_C^P \end{vmatrix} = \begin{vmatrix} A_{PP} & A_{PC} \\ A_{CP} & A_{CC} \end{vmatrix} \begin{vmatrix} X_P^P \\ X_C^P \end{vmatrix} + \begin{vmatrix} A_{PR}X_R^P+\tilde{Y}_P^P+J_P^P+FM_P^P \\ A_{CR}X_R^P+\tilde{Y}_C^P+J_C^P+FM_C^P \end{vmatrix}. \qquad (4.5)$$

As the prefectural distribution of J and FM for local goods are to be calculated simultaneously under Assumptions 4.3 and 4.4, the prefectural production of local goods can be obtained if X_R^P, $\tilde{Y}_P^P$ and $\tilde{Y}_C^P$ are given. However, the over-determination in our distribution model that the prefectural final demands for R-goods $\tilde{Y}_R^P$ are simultaneously specified helps us determine the prefectural net exports of R-goods as demand-supply imbalances within that prefecture.

$$FM_R^P = (I_R-A_{RR})X_R^P-A_{RP}X_P^P-A_{RC}X_C^P-\tilde{Y}_R^P-J_R^P \qquad (4.6)$$

The C-level computation in zone c is based on the balance equation,

$$X_C^c = A_{CC}X_C^c + (A_{CR}X_R^c+A_{CP}X_P^c+\tilde{Y}_C^c+J_C^c+FM_C^c). \qquad (4.7)$$

Similarly as in the P-level computation, the zonal production of C-level goods can be calculated from X_R^c, X_P^c and $\tilde{Y}_C^c$, which are given by the distribution models. Accordingly, the zonal net exports of R and P-goods can be obtained as zonal imbalances.

$$\left.\begin{aligned} FM_R^c &= (I_R-A_{RR})X_R^c-A_{RP}X_P^c-A_{RC}X_C^c-\tilde{Y}_R^c-J_R^c \\ FM_P^c &= -A_{PR}X_R^c+(I_P-A_{PP})X_P^c-A_{PC}X_C^c-\tilde{Y}_P^c-J_P^c \end{aligned}\right\} \qquad (4.8)$$

The basic procedures in the 3LIO model are summarized in Figure 4.1.

4.2. Distribution Models for Final Demand Items

The activity model, which is in charge of analyzing the flow aspects of the metropolitan activities, is designed to constitute a part of a general metropolitan simulation model. Thus we can expect that the spatial allocations of stock variables would be provided from a separate location model. In other words, the activity model is supplied with the allocations of the investment items, IR, IF, IGR and IG, by the location model, where they are determined in accordance with the zonal allocations of employment, population, housing, as well as the flow variables in the past. We leave

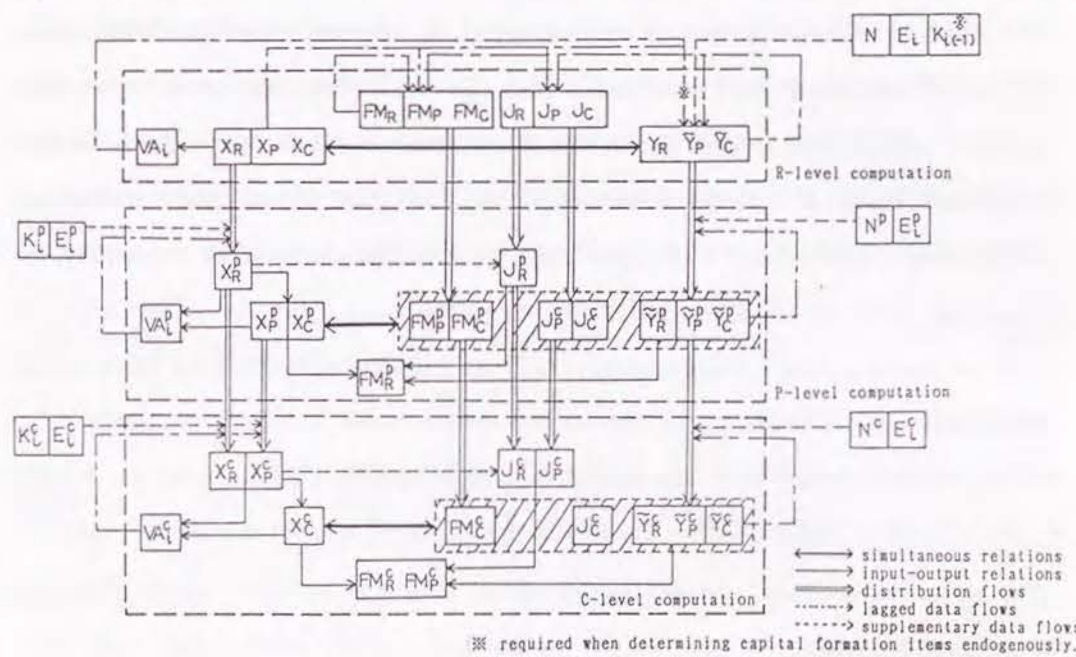

Figure 4.1. The three level input-output procedures.

the actual formulations for these items to the *auxiliary location submodel* to be discussed in Section 6.4. Thus in this section, it suffices to formulate distribution models for consumption items, C1 through C4.

From the discussion in Section 3.5, we basically describe the household consumption expenditures by eq.(3.21).†4

$$C2/N = \alpha_{20} + \alpha_{21}(C2_{-1}/N) + \alpha_{22}(VA/N) \qquad (3.21)$$

However, when we estimate the parameters from the pooling data concerning the seven prefectures over the five-year period, eq.(3.21) violates the sign condition even though it may be valid at the regional level. This could be explained by the fact that the smaller the spatial unit becomes, the less likely the economic transactions complete within that unit. One reason that we could not disregard such spillovers is attributable to the conceptual discrepancy between accounting of consumption and value added that the former is obtained as transactions by the residents while the latter is accounted at the places of production. And this discrepancy requires us to explicitly consider the income transfers among prefectures, associated with commuting.

Such a transfer might be approximated by the term $VA(N^p/N-E^p/E)$, where N^p and E^p represent the population and the number of employees in prefecture p, respectively, and the variables without superscripts represent the regional values. This corresponds to the fact that the income is supposedly proportional to population while the production is to employees. Thus the term is to approximate the transfer from the production site to the residential one. Consequently, we can rewrite eq.(3.21) to incorporate transfers at the prefectural level.

$$\frac{C2^p}{N^p} = \alpha_{20} + \alpha_{21}\frac{C2^p_{-1}}{N^p} + \alpha_{22}\frac{VA^p+VA(N^p/N-E^p/E)}{N^p} \qquad (4.9)$$

The model parameters are estimated using this expression. Note that eq.

†4. Here the parameters are changed to α_{2j} to comply with the notational rules in this chapter.

(4.9) is consistent w.r.t. to the regional aggregation, and eq.(3.21) is still valid at the regional level. That is, when eq.(4.9) is multiplied by N^p and summed over prefectures, we have

$$\begin{aligned} C2 = \Sigma_p C2^p &= \alpha_{20}\Sigma_p N^p + \alpha_{21}\Sigma_p C2^p_{-1} + \alpha_{22}\Sigma_p(VA^p+VA(N^p/N-E^p/E)) \\ &= \alpha_{20}N + \alpha_{21}C2_{-1} + \alpha_{22}VA. \end{aligned} \qquad (4.10)$$

The RHS of this expression is equivalent to eq.(3.20)', which is obtained by multiplying the regional population to eq.(3.21).

For the actual applications, the prefectural values are calculated by taking the Taylor expansion of the first-order around the regional values, C2/N.†5

$$C2^p = \left[\frac{C2}{N} + \alpha_{21}\left(\frac{C2^p_{-1}}{N^p} - \frac{C2_{-1}}{N}\right) + \alpha_{22}\left(\frac{VA^p+VA(N^p/N-E^p/E)}{N^p} - \frac{VA}{N}\right)\right]N^p \qquad (4.11a)$$

This is equivalent to considering that the regional per capita consumption is sufficiently close to those for the prefectures belonging to the Region. Then eq.(4.11a) is expected to give more stable results than using eq.(4.9), which calculates the entire amount of prefectural consumption $C2^p$ directly. Incidentally, as the regional values can be regarded as the "standard values" discussed in Section 3.5, we can avoid the problem associated with the constant term α_{20} with this expression. Elimination of the term which might reflect the zonal scales, at the same time, makes it possible to apply the similar formula to the C-level distributions, but the prefectural values are regarded as the first approximations in this case.

$$C2^c = \left[\frac{C2^p}{N^p} + \alpha_{21}\left(\frac{C2^c_{-1}}{N^c} - \frac{C2^p_{-1}}{N^p}\right) + \alpha_{22}\left(\frac{VA^c+VA^p(N^c/N^p-E^c/E^p)}{N^c} - \frac{VA^p}{N^p}\right)\right]N^c \qquad (4.11b)$$

Next we consider the consumption expenditures outside households C1, which correspond to welfare, social expenses and lodging allowances paid by firms. Since it is reasonable to assume such expenses are proportional to

†5. The first-order Taylor expansion might not be unique depending on whether to regard each term as a whole as an independent variable or to take partial derivatives for the individual variables constituting it. We employ the former view in formulating the distribution models.

the number of employees, we use the following in place of eq.(4.9).

$$\frac{C1^P}{E^P} = \alpha_{10} + \alpha_{11}\frac{C1^P_{-1}}{E^P} + \alpha_{12}\frac{VA^P+VA(E^P_{18}/E_{18}-E^P/E)}{E^P}, \tag{4.12}$$

where E_{18} represents the number of employees in the clerical business, which lists the managerial sections of R-level firms (Sectors 1 through 14) separately from their mother industries.[†6] Here the transfer term $VA(E^P_{18}/E_{18}-E^P/E)$ reflects the fact that many of such expenses are incurred where their main offices are located, rather than at the sites of production.

While the parameters are estimated for eq.(4.12), the predictions of local values are based on its first-order Taylor expansions.

$$C1^P = [\frac{C1}{E} + \alpha_{11}(\frac{C1^P_{-1}}{E^P} - \frac{C1_{-1}}{E}) + \alpha_{12}(\frac{VA^P+VA(E^P_{18}/E_{18}-E^P/E)}{E^P} - \frac{VA}{E})]E^P \tag{4.13a}$$

$$C1^C = [\frac{C1^P}{E^P} + \alpha_{11}(\frac{C1^C_{-1}}{E^C} - \frac{C1^P_{-1}}{E^P}) + \alpha_{12}(\frac{VA^C+VA^P(E^C_{18}/E^P_{18}-E^C/E^P)}{E^C} - \frac{VA^P}{E^P})]E^C \tag{4.13b}$$

Regarding the government consumptions, C3 and C4, the funds are allocated, for the most part, in accordance with the previous records. Thus we employ the inertial terms and the changes in numbers of employees in related sectors to represent organizational changes. We here regard the community and government services of the relevant level as such sectors. For the national expenditures we employ $\Delta EP_R = \Delta(E_{16}+E_{17})$, while the local ones are represented by $\Delta EP_L = \Delta(E_{28}+E_{29}+E_{33}+E_{34})$, where Δ denotes the changes from the previous period, viz. $\Delta EP_R = EP_R-EP_{R(-1)}$, for example. Considering the fact that the government spending is basically proportional

†6. The reason why we deal with the managerial segment of the industries separately is that the way they choose their locations are different from that of their mother industries. For instance, while manufacturing factories tend to prefer wider space and access to freight transportation, their main offices tend to choose center city locations.

The clerical business is considered only for R-level activities. This is due to the fact that the local activities are to be operated by smaller firms, and thus, it is relatively difficult to make distinction between managerial and non-managerial workers.

to population, we have the following expressions for estimating parameters.

$$\frac{C3^P}{N^P} = \alpha_{30} + \alpha_{31}\frac{C3^P_{-1}}{N^P} + \alpha_{32}\frac{\Delta EP^P_R}{N^P} \tag{4.14a}$$

$$\frac{C4^P}{N^P} = \alpha_{40} + \alpha_{41}\frac{C4^P_{-1}}{N^P} + \alpha_{42}\frac{\Delta EP^P_L}{N^P} \tag{4.14b}$$

As the government services are defined as self-consuming activities, possibilities of transfers are excluded at least in monetary terms. And the subsidies on the community services constitute a major portion of the government consumption. Accordingly, it appears unnecessary to consider transfer terms for these expenditures.

As is the case for the private consumptions, we employ the first-order Taylor expansions of the above equations for the local predictions. The prefectural distributions, for example, will be made in accordance with the following expressions.

$$C3^P = [\frac{C3}{N} + \alpha_{31}(\frac{C3^P_{-1}}{N^P} - \frac{C3_{-1}}{N}) + \alpha_{32}(\frac{\Delta EP^P_R}{N^P} - \frac{\Delta EP_R}{N})]N^P \tag{4.15a}$$

$$C4^P = [\frac{C4}{N} + \alpha_{41}(\frac{C4^P_{-1}}{N^P} - \frac{C4_{-1}}{N}) + \alpha_{42}(\frac{\Delta EP^P_L}{N^P} - \frac{\Delta EP_L}{N})]N^P \tag{4.15b}$$

Likewise the C-level distributions follow the expansions around the prefectural values.

The results of parameter estimations based on eqs.(4.9), (4,12), (4.14a) and (4.14b) are summarized in Table 4.1.[†7] Although the t-values for constants α_{i0} tend to be low, they will not affect the predicted values since the expanded forms are employed in the actual simulations. Moreover, by the virtue of hierarchical consistency that our formulations maintain, these parameters could commonly be used in some of the equations in the

†7. The variables expressed in monetary terms are in million yen, which are evaluated at the 1975 prices. For those compiled from income statistics, deflated values are readily available, while production related data are deflated using commodity-based inflators obtained through the method suggested in Section 3.3. The units of population and employments are number of persons.

Table 4.1. Parameters of distribution models for consumption items.

	i	α_{i0}	α_{i1}	α_{i2}	$\bar{R}^2$
C1	1	0.0673 (3.35)	0.4890 (3.23)	.00356 (2.20)	0.4400 df=32
C2	2	0.0370 (1.70)	0.9336 (20.91)	0.0398 (1.98)	0.9752 df=32
C3	3	-.00131 (1.77)	1.0461 (67.93)	4.2218 (3.65)	0.9929 df=32
C4	4	.00231 (0.90)	0.9939 (48.31)	2.4786 (2.26)	0.9865 df=32

Note: The column of $\bar{R}^2$ gives the determination coefficients adjusted to the degrees of freedom, and the values within the parentheses show the absolute t-values.

regional frame model, which will be discussed in Section 5.1.

Given the spatial allocation of the investment items, the local net final demand vectors, W^p and W^c, have now been determined. And with the converter matrix C, we can transform these itemized net final demands into the commodity based ones.

$$\hat{Y}^p = CW^p \quad \text{and} \quad \hat{Y}^c = CW^c \tag{4.16}$$

4.3. Distribution Models for Productions

As noted in Section 4.1, the 3LIO model requires a part of the commodity productions to be distributed over the localities separately from the mainstream of the input-output analysis. In the case of the net final demands, local distributions for all the commodities are determined at a time by eq.(4.16). On the contrary, the production distributions to a local level are required only for the commodities to be traded beyond that level as suggested by the BIO model. That is, i) R-level goods are to be distributed from the Region to C-level zones, ii) P-level goods are to be distributed from the prefectures to zones, and iii) no distributions are required for C-level goods.

The productions are distributed in proportion to the production capabilities of the localities. Such capabilities may be described as values of an aggregate production function of the sector. The following three

types of functions are considered at the prefectural level.

$$\text{(a) } \hat{X}_i^p=\alpha_i(K_i^p)^{\beta_i}(E_i^p)^{\gamma_i}, \text{ (b) } \hat{X}_i^p=\alpha_i(E_i^p)^{\gamma_i}, \text{ and}$$

$$\text{(c) } \hat{X}_i^p=\alpha_i(E_i^p)^{\gamma_i}\left(\frac{VA_{-1}^p/EU_{-1}^p}{VA_{-1}/EU_{-1}}\right)^{\delta_i}. \tag{4.17}$$

The first one is a typical Cobb-Douglas type function, which combines production assets K_i and number of employees E_i assigned to the sector. Since the sectorial data of the former are only available for the manufacturing sectors, 03 through 10, labor is considered to be a sole source of production in the remaining sectors.†8 The third expression incorporates certain external economies reflecting the average labor productivity per non-agricultural, non-mining employees, EU^p, in the locality.†9 In tertiary sectors, in particular, the sales per employee would accelerate with agglomeration of productions. The high productivity is also necessitated to pay off the higher rents.

Due to data limitations, the parameters are estimated log-linearly from the pooling data at the prefectural level. The hats attached to the LHS of eq.(4.17) identify that those values serve only as approximations to the prefectural productions, in the sense that the aggregative consistency, $\Sigma_p \hat{X}_i^p = X_i$, is not guaranteed by themselves. Hence it appears to be appropriate to use the distributive formulas where the regional amounts are distributed in proportion to the values obtained from eq.(4.17). From the

†8. The land is seemingly an indispensable input in agricultural sector. In an urbanized area like our study area, crops are chosen to produce the highest revenue from the limited land. Consequently, as far as productions are evaluated in monetary terms, land area is found not so effective to the production as might be expected. And as it is difficult to obtain dependable data on land areas for non-agricultural sectors, we do not consider land inputs explicitly in our production functions.

†9. In Sakai and Ando,[7] the agglomeration effects are considered in the form of an exponential term, i.e., the type (c) function has been given by $\hat{X}_i^p = \alpha_i(E_i^p)^{\gamma_i} \exp[\delta_i\{(VA_{-1}^p/EU_{-1}^p)-(VA_{-1}/EU_{-1})\}]$, instead. However, the sensitivity of the exponential function sometimes leads to infinitesimal results. Consequently, a power function is adopted for the actual simulations.

discussion in Section 3.5, it is possible to apply the parameters to the C-level zones even though they are estimated at the prefectural level, provided that the model is log-linear and distributive.

However, since many of the sectors related to capital formations, like construction sectors, are defined so as to produce non-tradable goods, to distribute the entire amount of productions would violate those definitions. Therefore, we here consider the inputs to be used to form capitals as captive to the locations where those formations are made. That is, defining the i-th good input to capital formations in prefecture p by

$$I_i^p = c_{i5}IR^p + c_{i6}IF^p + c_{i7}IGR^p + c_{i8}IG^p,$$

the production is calculated by the following formula.

$$X_i^p = I_i^p + (\hat{X}_i^p/\Sigma_p\hat{X}_i^p)(X_i - \Sigma_p I_i^p) \qquad (4.18a)$$

Deducting the input related to the capital formations, $X_i^p - \Sigma_{c\in p}I_i^c$ serves as the control total for the prefecture to which c belongs. Then the zonal production can be calculated by

$$X_i^c = I_i^c + (\hat{X}_i^c/\Sigma_{c\in p}\hat{X}_i^c)(X_i^p - \Sigma_{c\in p}I_i^c), \qquad (4.18b)$$

where $\hat{X}_i^c$ denotes the zonal estimate from eq.(4.17).

Table 4.2 summarizes the parameters of the production functions with the functional types selected being indicated for respective sectors. For sectors classified as to produce R-goods, those parameters would commonly be applied to both eqs.(4.18a) and (4.18b), while the latter equation only needs to be calculated for the P-level sectors.†10

The production functions of type (c) are employed only when both γ_i and δ_i demonstrate correct signs and are statistically significant at the 5 % level, with the only exception of sector 02 (Mining) whose last term to represent external effects is merely significant at the 13 % level. Incidentally, those sectors with δ_i < 1 might be regarded as activities that

†10. As the employees engaged in public works cannot be divided into the governmental levels which carry out the projects, productions of all three levels of public works, sectors 15, 27 and 32, are summed up to calculate the parameters of the corresponding production function.

Table 4.2. The parameters of production functions.

SECT	FUNC TYPE	α_i	β_i	γ_i	δ_i	R^2	SECT	FUNC TYPE	α_i	β_i	γ_i	δ_i	R^2
R 01	b	1094.1 (10.41)		0.4751 (8.37)		0.6276 (df=40)	R 16	b	4.7882 (3.84)		1.0484 (24.61)		0.9365 (df=40)
R 02	c	2.2401 (0.34)		1.2921 (3.98)	2.0096 (1.57)	0.2912 (32)	R 17	b	1.3761 (0.34)		1.0774 (11.29)		0.7553 (40)
R 03	a	5.1979 (3.10)	0.6597 (7.59)	0.3953 (4.26)		0.9200 (39)	R 18	b	2.4474 (5.19)		1.0019 (68.56)		0.9914 (40)
R 04	a	0.2693 (2.97)	1.0659 (10.57)	0.2551 (3.12)		0.9584 (39)	P 19	c	3.2414 (2.53)		1.1206 (19.43)	2.0255 (4.51)	0.9543 (32)
R 05	a	6.8679 (4.86)	0.4278 (8.27)	0.5660 (12.84)		0.9488 (39)	P 20	c	167.31 (7.06)		0.7402 (11.25)	3.2657 (6.90)	0.8678 (32)
R 06	a	1.3495 (2.32)	0.6445 (10.62)	0.5325 (8.43)		0.9945 (39)	P 21	b	0.9987 (0.01)		1.1829 (51.24)		0.9846 (40)
R 07	a	3.6729 (3.36)	0.5736 (16.05)	0.4398 (7.52)		0.9626 (39)	P 22	b	0.5847 (1.56)		1.1859 (36.07)		0.9694 (40)
R 08	a	4.3768 (2.50)	0.4457 (12.00)	0.6226 (11.48)		0.9165 (39)	P 23	b	0.7025 (1.10)		1.2296 (37.24)		0.9713 (40)
R 09	a	2.1883 (2.99)	0.7698 (11.74)	0.3406 (5.23)		0.9853 (39)	P 24	c	39.866 (14.53)		0.9184 (40.04)	0.5161 (2.25)	0.9837 (32)
R 10	a	0.3170 (2.44)	0.5361 (9.68)	0.7592 (16.50)		0.9637 (39)	P 25	b	2.7858 (6.87)		1.0660 (79.99)		0.9936 (40)
R 11	c	36.331 (6.90)		1.0887 (16.90)	2.1464 (4.43)	0.9479 (32)	P 26	b	3.3636 (7.68)		1.0779 (67.47)		0.9911 (40)
R 12	c	3.2035 (1.28)		1.1522 (12.91)	2.8819 (5.25)	0.8499 (32)	P 28	b	1.8228 (2.75)		1.0910 (52.94)		0.9856 (40)
R 13	b	3.1851 (7.67)		1.1673 (72.90)		0.9923 (40)	P 29	c	81.865 (19.94)		0.7504 (33.04)	0.7534 (4.01)	0.9778 (32)
R 14	b	1.7647 (2.52)		1.1247 (56.16)		0.9872 (40)	R 15 P 27	c	0.3076 (1.41)		1.2783 (16.47)	1.8724 (3.31)	0.9303 (32)

Note: Although the parameters are calculated from log-linear regressions, α_i's shown here are transformed to the ones in eq. (4.17), viz. the exponents of the regressed intercepts. The t-values shown within parentheses are those directly obtained from log-linear regressions. Degrees of freedom are: 39 for type (a), 40 for type (b) and 32 for type (c) regressions.

possess a public service outlook that they ought to allocate employees even to zones where only low productivity could be expected. Meanwhile, the fact that some of the t-values corresponding to the multiplicative terms α_i are statistically insignificant is less important since such terms are to be canceled out when incorporated in the distributive formulas.

4.4. Simultaneous Determination of Productions and Consumption Items

As eqs.(4.9) and (4.12) indicate, the private consumption items, C1 and C2, depend on the value added for the present period, which is defined as a part of the concurrent productions. This implies that the productions and those items ought to be determined simultaneously as illustrated in Figure 4.1. And this can be done essentially by partitioning the itemized net final demand vector W into two parts; the one which indirectly depends on the production vector X, and $\tilde{W}$ which does not.

Since the R-level computations are considered to be a part of the regional frame model, we here focus on the local ones leaving those for the

R-level to the next chapter. For the P-level computations, we have the following partition of W^p for prefecture p based on the dependency on X^p.

$$\begin{aligned} W^p &= (C1^p\ C2^p\ C3^p \ldots\ IG^p)^T = BX^p + \tilde{W}^p \\ &= (\alpha_{12}\ \alpha_{22}\ 0\ \ldots\ 0)^T (a_{0,1}\ \cdots\ a_{0,35})(X_1^p\ \ldots\ X_{35}^p)^T \\ &+ [C1(E^p/E)+\alpha_{11}(C1_{-1}^p - C1_{-1}(E^p/E))+\alpha_{12}VA(E_{18}^p/E_{18}-2E^p/E), \\ &\quad C2(N^p/N)+\alpha_{21}(C2_{-1}^p - C2_{-1}(N^p/N))-\alpha_{22}VA(E^p/E),\ C3^p,\ \ldots,\ IG^p]^T, \end{aligned} \tag{4.19}$$

where a_{0j} is the input coefficient for value added in sector j, which is assumed to be invariant over the Region by *Assumption 4.1*. Then the local level balance equation (4.5) can be rewritten with partitions of vectors and matrices corresponding to non R-level goods denoted by L.

$$X_L^p = A_{LL}X_L^p + [A_{LR}X_R^p + C_L(B_RX_R^p + B_LX_L^p) + C_L\tilde{W}^p + Z_LX_L^p], \tag{4.5'}$$

where Z_L is a diagonal matrix given by

$$Z_L = \mathrm{diag}\{(J_i + FM_i)/X_i \mid i \in L\}, \tag{4.20a}$$

which is in conformity with *Assumptions 4.3* and *4.4*.

It must be noted that the prefectural productions of R-level goods X_R^p would have been determined prior to this stage through the production distribution models stated above. Accordingly, all of the prefectural productions would be determined when those for local goods are obtained.

$$X_L^p = [I_L - (A_{LL} + C_LB_L + Z_L)]^{-1}[(A_{LR} + C_LB_R)X_R^p + C_L\tilde{W}^p] \tag{4.21a}$$

And this enables us to calculate the value added, $VA^p = \Sigma_j a_{0j}X_j^p$, and thus, the consumption items for the prefecture.

Only the productions for C-level goods are to be calculated from the C-level balance equation as those for both R and P-level goods are subject to prior distribution. Similarly as in the above case, we dichotomize the itemized net final demand vector W^c for zone c.

$$W^c = BX^c + \tilde{W}^c,$$

where the second term of the RHS is independent of the zonal productions, and given by

$$\begin{aligned} \tilde{W}^c = [&C1^p(E^c/E^p)+\alpha_{11}(C1_{-1}^c - C1_{-1}^p(E^c/E^p))+\alpha_{12}VA^p(E_{18}^c/E_{18}^p - 2E^c/E^p), \\ &C2^p(N^c/N^p)+\alpha_{21}(C2_{-1}^c - C2_{-1}^p(N^c/N^p))-\alpha_{22}VA^p(E^c/E^p),\ C3^c, \ldots,\ IG^c]^T. \end{aligned} \tag{4.22}$$

Defining the diagonal matrix Z_C^p for prefecture p to which zone c belongs by

$$Z_C^p = \mathrm{diag}\{(J_i^p + FM_i^p)/X_i^p \mid i \in C\}, \tag{4.20b}$$

the zonal balance equation (4.7) can be rewritten as follows.

$$X_C^c = A_{CC}X_C^c + [A_{CR}X_R^c + A_{CP}X_P^c + C_C(B_RX_R^c + B_PX_P^c + B_CX_C^c) + C_C\tilde{W}^c + Z_C^pX_C^c] \tag{4.7'}$$

Rearranging this expression, we obtain the zonal production vector for C-level goods.

$$X_C^c = [I_C - (A_{CC} + C_CB_C + Z_C^p)]^{-1}[(A_{CR} + C_CB_R)X_R^c + (A_{CP} + C_CB_P)X_P^c + C_C\tilde{W}^c] \tag{4.21b}$$

Combining this with the pre-distributed productions of higher commodity levels, we can determine all the consumption items in the C-level zones. And thus the aim of the activity model, to break down all the flow variables to the minimal spatial units in the Region, has now been achieved.

The discussion so far has focused on how we may distribute the regional amounts to zones, upon the availability of such values. Then the next step is to determine those regional amounts, viz. the regional final demand items along with the R-level input-output calculations, which will be the major subject in the next chapter.

References

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CHAPTER 5

THE REGIONAL FRAME MODEL

The regional frame model is designed to determine the final demand items, including consumptions, investments, net increase in stocks and the net export, as well as the employments at the regional level. Among them, the latter three factors are determined by sectors. We aimed at formulating each of these models in this chapter. Most formulas, except for the ones concerning the employments, are directly related to the input-output computations discussed in the previous chapter.[1]

5.1. Net Final Demand Items

5.1.1. Consumption items and regional productions

As mentioned in Section 3.5, most model parameters are estimated from the pooling data collected at the prefectural level to secure a sufficient degree of freedom. Meanwhile, as all the distribution models in Section 4.2 are formulated on the per capita or per employee basis, they are independent of the size of the spatial unit. And the consistency regarding regional aggregations is guaranteed for the consumption items as illustrated in eq.(4.10). Hence, it is possible to use the common parameters to the distribution models as far as those items are concerned. In other words, eq.(4.10) indeed gives an unbiased estimate for the regional household consumption, and a similar argument applies to the other three consumption items as well.

Accordingly, we have the following expressions for estimating the consumption items at the regional level, where the parameters shown in Table 4.1 have been incorporated.

$$C1 = 0.0673\ E + 0.4890\ C1_{-1} + 0.0036\ VA \qquad (5.1a)$$

$$C2 = 0.0370\ N + 0.9336\ C2_{-1} + 0.0398\ VA \qquad (5.1b)$$

$$C3 = -0.0013\ N + 1.0461\ C3_{-1} + 4.2218\ \Delta EP_R \qquad (5.1c)$$

$$C4 = 0.0023\ N + 0.9939\ C4_{-1} + 2.4786\ \Delta EP_L \qquad (5.1d)$$

The productions X for the present period are related to the value added VA in the RHS of the first two equations, and thus, the consumption items must be determined simultaneously with them. Similarly as is the case in Section 4.4, this can be done by partitioning the itemized net final demand vector W into two terms on the ground of the dependency on X.

$$\begin{aligned} W &= (C1\ C2\ C3\ \ldots\ IG)^T = BX + \tilde{W} \\ &= (\alpha_{12}\ \alpha_{22}\ 0\ \ldots\ 0)^T(a_{0,1}\ \cdots\ a_{0,35})(X_1\ \cdots\ X_{35})^T \\ &+ (\alpha_{10}E+\alpha_{11}C1_{-1}\ \ \alpha_{20}N+\alpha_{21}C2_{-1}\ \ C3\ \ldots\ IG)^T, \end{aligned} \qquad (5.2)$$

where a_{0j} is the input coefficient for value added in sector j. As the regional (gross) final demand vector Y can then be written as

$$Y = \tilde{Y} + J + FM = C(BX + \tilde{W}) + J + FM, \qquad (5.3)$$

we can rewrite the regional balance equation (4.4) as follows.

$$X = AX + C(BX + \tilde{W}) + J + FM \qquad (4.4)'$$

Rearranging this expression w.r.t. X, we can easily obtain a relation which does not explicitly contain VA.

$$X = [I - (A+CB)]^{-1}[C\tilde{W} + J + FM] \qquad (5.4)$$

The regional value added can then be calculated by $VA = \Sigma_j a_{0j} X_j$, from which C1 and C2 are determined posteriorly through the first two equations of eq.(5.1).

5.1.2. Housing investments

As we leave their spatial distributions to the location model, the investment items need to be determined only at the regional level. Among the four investment items, we first consider the housing investments, both private and government. We here assume that these items depend on the value added in the previous period VA_{-1} and the population increase ΔN in the present period, which is exogenous to the model. The latter is expected to represent the new demand and used in the form of $\Delta\tilde{N} \equiv \max(\Delta N, 0)$, while the former corresponds to the maintenance costs at large.

Although the distribution models, of the kind discussed in Section 4.2, are not required for these items, we still need to estimate the parameters at the prefectural level due to data limitations. For example, the parameters for the private housing investment IR are obtained from the prefectural data using

$$IR^p = \alpha_{50} + \alpha_{51} VA^p_{-1} + \alpha_{52}\Delta\tilde{N}^p. \qquad (5.5)$$

As discussed in Section 3.5, it is possible to apply the same parameters to the calculation of its regional value provided that this expression gives an unbiased estimate of the prefectural investment. Namely, the regional value can be obtained by summing up eq.(5.5) w.r.t. prefectures.

$$IR = \Sigma_p IR^p = \alpha_{50} n + \alpha_{51}\Sigma_p VA^p_{-1} + \alpha_{52}\Sigma_p \Delta\tilde{N}^p = \alpha_{50} n + \alpha_{51} VA_{-1} + \alpha_{52}\Delta\tilde{N},$$

where n is the number of prefectures in the Region, which is seven for our study area including Tokyo Metropolis. Thus to apply the prefectural estimates to the regional level, it is only necessary to multiply the intercepts by the number of prefectures within the Region.

As the same argument also applies to the government housing investment, IGR, we have the following expressions for the regional housing investments.

$$\underset{(0.24)}{IR = -39501} + \underset{(33.35)}{0.0488\ VA_{-1}} + \underset{(12.23)}{2.916\ \Delta\tilde{N}}, \quad \bar{R}^2 = 0.9705,\ df=32, \qquad (5.6)$$

$$\underset{(0.02)}{IGR = -824.6} + \underset{(9.72)}{0.00291 VA_{-1}} + \underset{(2.33)}{0.1140\Delta\tilde{N}}, \quad \bar{R}^2 = 0.7318,\ df=32, \qquad (5.7)$$

where the parameters are calculated from the data collected between 1975 and 80. However, we have only five effective years of observations due to the lagged variable, VA_{-1}, contained in the above expressions.

5.1.3. Non-housing investments

These items can be subdivided into three categories, viz. the government capital formation except housing, the manufacturing and non-manufacturing capital formations. Among them, only the manufacturing ones are to be formulated on the sectorial basis.

i) Government capital formation except housing IG: The same explanatory variables as for the housing investments are employed for this item. Consequently, we have the following expression with parameters estimated at the prefectural level.

$$IG = \underset{(3.74)}{1.042\times10^{6}} + \underset{(21.83)}{0.0540}\, VA_{-1} + \underset{(2.24)}{0.9022}\, \Delta\tilde{N}, \quad \bar{R}^2 = 0.9355,\ df=32. \tag{5.8}$$

ii) Manufacturing capital formation ΔK_i $(i=3,\ldots,10)$: It is a common practice to consider the investment as being the difference between the optimal stock and the existing one.2) And the former could be predicted from either Jorgenson's approach or the acceleration principle.3) Accordingly, we here consider these two predictions in the form of a linear combination.

$$\Delta K_i = \underset{(0.57)}{-7339.} + \underset{(1.74)}{0.0414} \frac{V_{40i(-1)}}{\gamma+\delta_i} + \underset{(2.74)}{0.4935} \frac{K_{i(-1)}X_{i(-1)}}{X_{i(-2)}} \underset{(1.81)}{-0.4139}(1-\delta_i)K_{i(-1)},$$
$$\bar{R}^2=0.8745,\ df=28, \tag{5.9}$$

where K_i is the manufacturing capital, X_i is the production, and V_{40i} is the operating surplus in sector i.†1 γ and δ_i are the official discount and the capital depreciation rates, respectively, which are exogenous to the model, and thus, $\gamma+\delta_i$ gives the effective capital cost.

The first term corresponds to the Jorgenson's optimal capital stock, while the second term is the expected needs for capital provided that the production expands at the same rate as the previous period. The third term is the existing stock after depreciation which is to be subtracted from the present needs, and thus the sign of this term is expected to be negative.

Unlike the previous items, parameters for this model are estimated from the regional data, i.e., we have 32 effective observations that correspond to 8 sectors over a four-year period, due to the use of the second-order lags. Moreover, in response to the difference in sizes of

†1. The subscript 40 for the operating surplus and 41 for the depreciation of fixed capital, respectively, correspond to the row numbers in the regional input-output tables shown in Tables A.1 and A.2.

industries, a GLS estimation is employed for this item with a weight proportional to the reciprocal of $K_{i(-1)}$.

iii) Non-manufacturing, non-housing capital formation ΔK_N: This category represents the investments associated with the sectors which entail the symbol N in Table 3.2, viz. activities other than Sectors 3 through 10, 17, 29 and 34. Likewise the variables with the subscript N identify the sums over such sectors. It must be noted that the government services are not taken into account since the investments by the public sector are excluded from the corresponding data.†2

As statistics are not available on the existing stocks, we employ the depreciation of fixed capital V_{41N} as a proxy to those. By the same reasoning, the capital depreciation rate δ cannot be calculated for this case. Since this item can only be dealt in a lump-sum form, it is necessary to use the prefectural data to secure a necessary degree of freedom. Thus the parameters are determined from the following equation at the prefectural level.

$$\Delta K^P_N = a_{60}+a_{61}[V^P_{40N(-1)}+V_{40N(-1)}(D^P_{N(-1)}/D_{N(-1)}-X^P_{N(-1)}/X_{N(-1)})]+a_{62}V^P_{41N(-1)}, \tag{5.10}$$

where D represents the net demand, which is the sum of intermediate demands and the net final demand, given by

$$D_i = \Sigma_j a_{ij}X_j + \tilde{Y}_i. \tag{5.11}$$

The term within brackets in eq.(5.10) corresponds to the Jorgenson's approach with considerations of transfers of operating surplus to fill in the discrepancies between distribution of demands and production capacities. Suppose that this term represents the expected capital stock K^*. Then the investment would comprise two segments, i.e., maintenance costs of the existing stock $c(1-\delta)K_{-1}$ with some positive constant c, and the new

†2. The data for this category are available in the form of private non-housing capital formation, from which the manufacturing formation is deducted. We here consider the community services as being a part of the category since a reasonable margin of such services is provided by the private sector.

investment to generate K^*. Thus we have $\Delta K = K^* + (c-1)(1-\delta)K_{-1}$, where the second term could either be positive or negative. Summing up eq.(5.10) over prefectures, the following result on the regional non-manufacturing, non-housing investment emerges with the transfer term canceled out.

$$\Delta K_N = \underset{(1.59)}{-631504} + \underset{(3.58)}{0.3111}\, V_{40N(-1)} + \underset{(7.48)}{1.010}\, V_{41N(-1)}, \quad \bar{R}^2=0.9875,\ df=32. \qquad (5.10)'$$

Combining results from eq.(5.9) and the above, the total private investment is then calculated from

$$IF = \Sigma_{i=3}^{10}\Delta K_i + \Delta K_N. \qquad (5.12)$$

5.2. Net Increase in Stocks and Net Export

These items are calculated in two phases. First the total amount is computed, and then distributed over commodities. This is necessitated by the data restriction that only the total amounts are available annually from the prefectural accounts, and their commodity compositions can be observed from the input-output tables compiled every five years, i.e., 1975 and 80 concerning our study period.

5.2.1. Net increase in stocks

Since this item is considered to be a kind of misadjustment between production and demand, the following expression is employed for the total amount J, whose parameters are determined from the prefectural data.

$$J = \underset{(0.81)}{-56612} + \underset{(4.98)}{0.00261}\, D_{J(-1)} - \underset{(4.51)}{0.1060}\Delta XD_{J(-1)}, \quad \bar{R}^2= 0.6566,\ df=25, \qquad (5.13)$$

where D_J represents the summation of net demands D_i, which is defined in eq.(5.11), over 27 sectors which entail the symbol J in Table 3.2. The remaining 8 sectors without this symbol; public works (15, 27, 32), government services (17, 29, 34), clerical business (18), and residential building (20), are defined to possess neither net increase in stocks nor net export in the input-output tables. Meanwhile, XD_i is the difference between production X_i and net demand D_i, and thus,

$$\Delta XD_{J(-1)} = \Sigma_{i\in J}[\Delta X_{i(-1)} - \Delta D_{i(-1)}], \qquad (5.14)$$

where the summation is taken for the 27 sectors mentioned above.

The fact that the sign of the parameter for this term is negative suggests the fluctuating nature of the item. The variable XD represents excessive production, and if XD is increasing over the previous period, the firms would try to decrease their inventory. The first term corresponds to the motivation to build up the inventory when the demand is strong.

The total amount obtained by eq.(5.13) is distributed over commodities to obtain the net increase in stocks J_i for respective commodities through the expression, which is standardized with the production $X_{i(-1)}$ of the previous year.

$$\frac{J_i}{X_{i(-1)}} = \alpha_{70} + \alpha_{71}\frac{D_{i(-1)}}{X_{i(-1)}} + \alpha_{72}\frac{\Delta XD_{i(-1)}}{X_{i(-1)}} \qquad (5.15)$$

Although the parameters are estimated for this expression, the predictions are made by taking the Taylor expansion around the average over commodities, $J/X_{J(-1)}$, which is consistent w.r.t. aggregation.

$$J_i = [\frac{J}{X_{J(-1)}} + \alpha_{71}(\frac{D_{i(-1)}}{X_{i(-1)}} - \frac{D_{J(-1)}}{X_{J(-1)}}) + \alpha_{72}(\frac{\Delta XD_{i(-1)}}{X_{i(-1)}} - \frac{\Delta XD_{J(-1)}}{X_{J(-1)}})]X_{i(-1)} \qquad (5.16)$$

The parameters are summarized in Table 5.1 along with those for commodity distributions of the next item, the regional net export.

Table 5.1. Parameters for commodity distributions of net increase in stocks and net export.

	i	α_{10}	α_{11}	α_{12}	$\bar{R}^2$
J	7	-.00627 (1.79)	.00602 (1.76)	-0.0513 (1.45)	0.9065 df=24
FM	8	.00299 (2.29)	0.8022 (220.)	0.2606 (4.93)	0.9994 df=24

Note: The notes on $\bar{R}^2$ and the t-values in Table 4.1 also apply to J. However, as those for FM are based on nonlinear regression, they are replaced by SSR/SST (the regressed sum of squares over the total sum of squares) and the asymptotic t-values, respectively.

5.2.2. Net export

This item is also observed as an imbalance between production and demand. However, unlike the previous item, it would reflect the customs of trade intrinsic to the Region considered. In this regard, the expression for the total amount includes the lagged value of itself.

$$FM = \underset{(0.65)}{54031} + \underset{(38.72)}{0.7777}\, FM_{-1} + \underset{(3.07)}{0.1232}\, \Delta XD_{J(-1)}, \qquad \bar{R}^2 = 0.9832,\ df=25. \tag{5.17}$$

The fact that the parameter associated with the term defined in eq.(5.14), viz. the change in production-demand imbalances, is positive implies that such a surplus would accelerate the export.

Accordingly, the basic formula for commodity breakdown is given by

$$\frac{FM_i}{X_{i(-1)}} = \alpha_{80} + \alpha_{81}\frac{FM_{i(-1)}}{X_{i(-1)}} + \alpha_{82}\frac{\Delta XD_{i(-1)}}{X_{i(-1)}}. \tag{5.18}$$

Due to the lagged variables in the formula and the fact that the LHS is only observable in 1975 and 80, we successively substitute $FM_{i(-1)}$ in the RHS by the same equation (5.18) concerning the previous period. Consequently the following fifth-order equa tion is resulted, from which parameters shown in Table 5.1 can be estimated nonlinearly.

$$FM_i(80)/X_i(79)$$

$$= \frac{\alpha_{80}}{X_i(79)}(X_i(79)+\alpha_{81}X_i(78)+\alpha_{81}^2X_i(77)+\alpha_{81}^3X_i(76)+\alpha_{81}^4X_i(75)) + \frac{\alpha_{81}^5}{X_i(79)}FM_i(75)$$

$$+ \frac{\alpha_{82}}{X_i(79)}(\Delta XD_i(79)+\alpha_{81}\Delta XD_i(78)+\alpha_{81}^2\Delta XD_i(77)+\alpha_{81}^3\Delta XD_i(76)+\alpha_{81}^4\Delta XD_i(75))$$

As is the case for the net increase in stocks, the expression obtained from the Taylor expansion of eq.(5.18) is used for the actual predictions.

$$FM_i = [\frac{FM}{X_{J(-1)}} + \alpha_{81}(\frac{FM_{i(-1)}}{X_{i(-1)}} - \frac{FM_{(-1)}}{X_{J(-1)}}) + \alpha_{82}(\frac{\Delta XD_{i(-1)}}{X_{i(-1)}} - \frac{\Delta XD_{J(-1)}}{X_{J(-1)}})]X_{i(-1)} \tag{5.19}$$

5.3. Sectorial Employments

The regional variables discussed above can be classified as the flow

variables, and are directly related to the input-output computations. In this section, we discuss the only stock variable to be determined in the regional frame model, viz. the regional employments. Similar to the last two items discussed in the previous section, we first obtain the total amount, which is distributed over activities.†3 The difference is that due to nonlinearity associated with the sectorial employment function, we cannot expect the aggregative consistency w.r.t. sectors.

In our model, the regional population N is assumed to be given exogenously. Then the prediction of total employment becomes equivalent to that of employment rate against population, which is unity less the unemployment rate, if we assume that a certain margin of population constitutes the labor force. Apparently, it would be natural to apply the idea of the Phillips curve, which links the unemployment rate with the rate of wage changes,[4] to the formulation of the number of employees. Nevertheless, we decide to adopt a formula similar to those for the consumption items due to data limitations. That is, while we must estimate the relevant parameters from the prefectural data, there would be a question about the reliability of those labor-related statistics at the local level. Considering the consistency w.r.t. spatial aggregation, we have the following expression at the prefectural level.

$$\frac{E^p}{N^p} = \underset{(1.98)}{-0.0121} + \underset{(387.)}{0.9882}\frac{E^p_{-1}}{N^p} + \underset{(4.09)}{0.0282}[V^p_{39(-1)} + V_{39(-1)}(\frac{N^p_{-1}}{N_{-1}} - \frac{E^p_{-1}}{E_{-1}})]\frac{1}{N^p}$$

$$\underset{(4.45)}{-0.0262}[\frac{V^p_{39(-1)}}{V_{39(-1)}} - \frac{E^p_{-1}}{E_{-1}}]\frac{N}{N^p}, \qquad \bar{R}^2 = 0.9998,\ df=31, \tag{5.20}$$

where V_{39} denotes the *compensation of employees* or the total wage payment.

†3. It is possible to calculate the sectorial employments directly without calculating the total value. For example, the model by the Economic Council of Japan[2] calculates the employment directly w.r.t. its 14 sectors. However, when we have a detailed sectorial classification, it is difficult to obtain the stable results. In other words, we consider the control total for the sectorial employments to secure their stability.

While the employment rate is evaluated at the place of residence, the wages are paid at the place of employment. For this reason, the last two terms are employed to represent the income transfers and the wage differentials. Namely, the second term, excluding the intercept, gives an estimate of wages received by residents, where the wages from the job site other than the prefecture in question come at the rate of regional average. The positive parameter assigned to this term implies the mechanism of labor supply that the supply would increase with the increase in the wage earning. On the other hand, the third term indicates the labor productivity, and the negative parameter implies the mechanism of labor demand that the entrepreneur tries to curtail labor where higher wages are required.

Multiplying eq.(5.20) by the prefectural population N^P and summing up over prefectures, we have the expression for the regional employment.

$$E = -0.0121\ N + 0.9882\ E_{-1} + 0.0282\ V_{39(-1)}, \qquad (5.21)$$

where the last term has been eliminated due to the spatial aggregation.

To formulate the sectorial employments, we consider the following profit maximizing problem based on a Cobb-Douglas type production function.

$$\max\ \pi = p\alpha K^{\beta} E^{1-\beta} - rK - wE,$$

where r and w are the capital rent and the wage rate, respectively. The first-order condition, $E/K = (1-\beta)r/\beta w$, is straightforward. It can also be written with the capital rent r eliminated, viz. $E/K = (\alpha(1-\beta)p/w)^{1/\beta}$, or

$$\ln E = (1/\beta)\ln(\alpha(1-\beta)) + \ln K - (1/\beta)\ln(w/p).$$

When using the monetary input-output table, the product price is unity by definition, and the wage rate in Sector i can be described as $w_i = V_{39i}/E_i$. Substituting the capital depreciation V_{41i} for the capital K_i, we have the following formula, which is to be calibrated w.r.t. sectors over the five year period.

$$\ln \tilde{E}_i = \alpha_i + \beta \ln V_{41i(-1)} - \gamma \ln(V_{39i(-1)}/E_{i(-1)}), \qquad (5.22)$$

where the parameters α_i and β are redefined, and the sectorial differences are considered only in terms of the intercept α_i. The parameters for this

formula are summarized in Table 5.2.[†4] Meanwhile, the estimates from this equation, $\hat{E}_i$, are to be regarded as the tentative ones, and should be adjusted with the total employment calculated from eq.(5.21).

Eq.(5.22) cannot be applied to Sector 18 (Clerical business) as its capital depreciation is not defined. Hence, its tentative value is calculated from the following equation whose parameters are estimated at the prefectural level.

$$\underset{}{\hat{E}_{18}} = \underset{(16.96)}{-304537} + \underset{(162.)}{5.756} \sum_{i=1}^{14} a_{18i}\hat{E}_i, \qquad \bar{R}^2=0.9984,\ df=40. \qquad (5.23)$$

As mentioned in Section 4.2, this sector corresponds to the managerial workers in Sectors 1 through 14. This expression assigns the weights to the tentative employees of those mother industries calculated above in accordance with the input coefficients from Sector 18.

Finally, the results from eqs.(5.22) and (5.23) are combined to

Table 5.2. Parameters for the sectorial employments.

	Params. (t-val)		Params. (t-val)		Params. (t-val)
α_1	0.5769(15.11)	α_{13}	1.3654(21.31)	α_{28}	3.1306(25.87)
α_2	0.6536(14.62)	α_{14}	2.3041(31.22)	α_{29}	4.0526(20.89)
α_3	1.7480 (5.93)	α_{16}	3.1165(17.49)	α_{30}	2.8950(52.40)
α_4	2.2914(10.93)	α_{17}	3.3575(20.79)	α_{31}	2.6046(42.34)
α_5	1.7510 (4.03)	α_{19}	1.2652 (8.01)	α_{33}	3.0121(59.44)
α_6	2.3579(13.45)	α_{20}	2.5825(41.68)	α_{34}	4.0593(22.16)
α_7	0.6041(122.6)	α_{21}	2.0805(10.54)	α_{35}	2.5440 (7.89)
α_8	1.4119(23.97)	α_{22}	2.8093(25.23)	α_C	1.8552 (5.09)
α_9	1.9075 (1.49)	α_{23}	1.2333(40.14)	β	0.9494(30.38)
α_{10}	-1.6761(17.40)	α_{24}	1.0126(17.82)	γ	0.9399(27.44)
α_{11}	-0.2212(80.96)	α_{25}	2.6393(80.56)	R^2	0.9999
α_{12}	1.9776 (4.66)	α_{26}	1.7364 (5.58)	df	126

Note: The constant terms are calculated from a regression with a class variable corresponding to the 32 sectors considered. As the one for the public works α_C is taken as the basis, its t-value is replaced by the one corresponding to the intercept.

†4. By the same reasoning as to estimate the production function in Section 4.3, it is statistically impossible to divide the employees engaged in public works into the three levels. Thus the employees in all three sectors are combined and designated by the symbol C in Table 5.2. That is, $E_C = E_{15}+E_{27}+E_{32}$.

determine the final predictions which are consistent with the total employment given by eq.(5.21).

$$E_i = (\hat{E}_i / \Sigma_i \hat{E}_i) E \qquad (5.24)$$

5.4. Use of Standard Values

While the models formulated above may directly be used to predict the regional frame values, there might be occasions where a set of dependable estimations are available from some other macro-econometric model.†5 In such cases, it is advantageous to incorporate these results into our model since many of the regional economic statistics are to be determined in connection with the rest of the world, which are beyond the realm of our model. The use of exogenous sequences is also desirable from a practical viewpoint so as to facilitate evaluations of various scenarios of the economic growth.

Such exogenous information can be incorporated through exactly the same way in which we calculate the local or commodity distributions of the regional values, viz. by using the Taylor expansion. For example, suppose that the basic relation is given by eq.(3.17), and a set of dependable estimates (X^O, Y^O) are given exogenously. Then the Taylor expansion,

$$Y = Y^O + \Sigma_j a_j (X_j - X_j^O), \qquad (3.17)'$$

would involve smaller errors than to use eq.(3.17) since we can avoid a part of the errors which would accompany the estimation of Y^O by regarding (X^O, Y^O) as the true combination.†6

†5. The model known as the *Amano-Fujita model*[5] is a typical multi-regional model with a specific emphasis on the interregional trades among nine subregions constituting Japan. This type of models could be used as the one supervising the regional frame. Although there have been a number of multi-regional econometric models, they tend to rely on the regional dummys.[6] In this sense, an authentic macro-econometric approach appears to be insufficient for a detailed regional analysis. Hence, our minimal requirement is a duo-regional model which would interface our Region with the configurations of the rest of the world, which might be obtained as an extension of the AGE model.[7]

The standard values could be incorporated into all the formulations concerning consumption expenditures and investments; equations (5.1), (5.6) through (5.9), and (5.10)'. For example, C2 and IR could be calculated from their standard values, respectively, as follows.

$$C2 = C2^O + a_{21}(C2_{-1} - C2^O_{-1}) + a_{22}(VA - VA^O),$$
$$IR = IR^O + a_{51}(VA_{-1} - VA^O_{-1}).$$

The reason why the term corresponding to $\Delta\tilde{N}$ in eq.(5.6) disappears in the latter expression is that the regional population N is assumed to be exogenous to our model. And by the same reason, the term N/N^O that appears in conjunction with the Taylor expansion of eq.(3.21) becomes unity.

The standard values for the remaining two items, the net increase in stocks and the net export, can be given either in the forms of totals or their commodity compositions. If the former is the case, the commodity breakdowns are to be calculated from eqs.(5.16) and (5.19), which do not require the commodity-based standard values. Otherwise, we might directly start from those equations without calculating the total values. The equations which incorporate the standard values can be obtained by replacing J, FM, X_J, D_J and ΔXD_J in eqs.(5.16) and (5.19) by J_i^O, FM_i^O, X_i^O, D_i^O and ΔXD_i^O, respectively.

Although all the aforementioned variables are related to the input-output analysis to some extent, there is a different category of variables to be determined in the regional frame model, viz. those related to the regional employments. The similar argument as for the balancing items is also applicable to this case regarding whether the standard values are given on the sectorial basis or not. When only the total one is available, the approximation based on E^O could be calculated using eq.(5.21).

†6. Let ε and ε_1 denote the errors associated with the estimations of Y and Y^O, respectively, in eq.(3.17). Then if the errors ε_2 associated with eq.(3.17)' is independent of ε_1, we have $Var(\varepsilon)=Var(\varepsilon_1)+Var(\varepsilon_2) \gtrsim Var(\varepsilon_2)$.

$$E = E^{o} + 0.9882(E_{-1} - E^{o}_{-1}) + 0.0282(V_{39(-1)} - V^{o}_{39(-1)}) \quad (5.25)$$

On the other hand, when the standard values for the sectorial employments are available, those values can be incorporated in eq.(5.22) using its exponential form. There might be a few alternative formulas depending on the way to deal with independent variables. One such formula would be

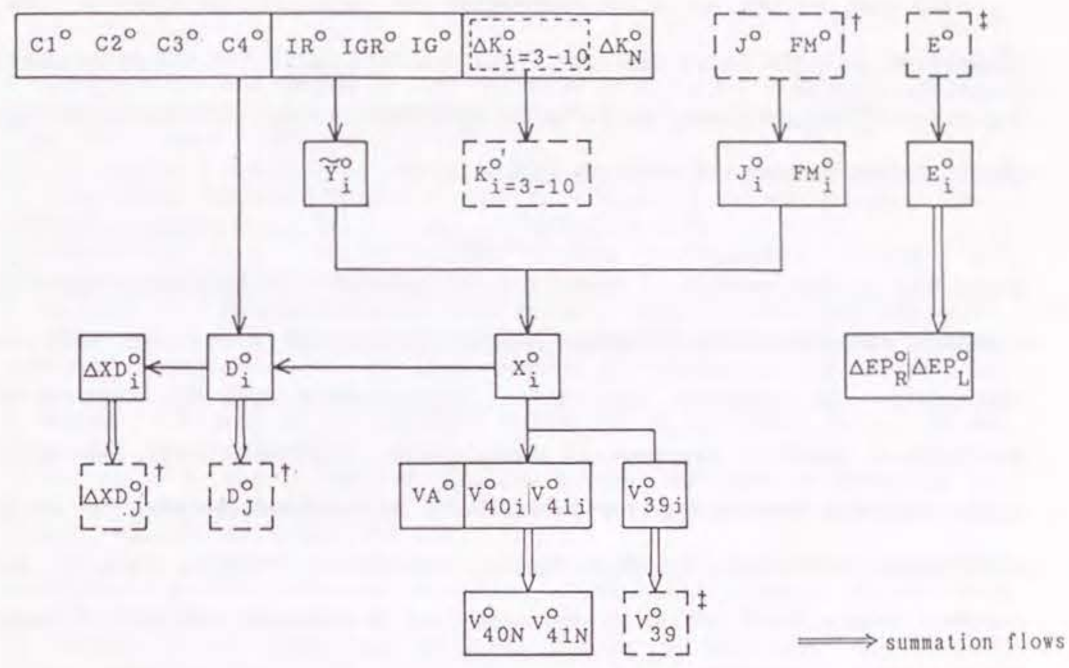
$$E_i = E^{o}_i + \beta\left(\frac{E^{o}_i}{V^{o}_{41i(-1)}}\right)(V_{41i(-1)} - V^{o}_{41i(-1)}) - \gamma\left(\frac{E^{o}_i E^{o}_{i(-1)}}{V^{o}_{39i(-1)}}\right)\left(\frac{V_{39i(-1)}}{E_{i(-1)}} - \frac{V^{o}_{39i(-1)}}{E^{o}_{i(-1)}}\right). \quad (5.26)$$

In this case, the total employment is to be calculated posteriorly from this result. However, it must be noted that eq.(5.26) does not maintain the aggregative consistency. Thus when we choose to use the prediction based on eq.(5.25) as the control total to the sectorial predictions, it is necessary to appeal to eq.(5.24) by regarding the LHS of eq.(5.26) as the tentative prediction, $\hat{E}_i$.

It is also noteworthy that the standard values cannot necessarily be given independently. In other words, as some of the variables are closely related to the others, those dependent variables must be computed from independent ones in accordance with certain definitive relations. That is, the standard values for the variables listed at the top of Figure 5.1 can only be given independently,[†7] and the rest of the variables are to be determined in connection with those independent variables.

The relation upon which the variables depend on the other variables can be classified into three categories. One is the simple aggregative relations identified by the double-lined arrows in the figure. Those belonging to the second category are to be computed in accordance with the

†7. When the standard values for the net increase in stocks and net export are available on the sectorial basis, they can be given independently instead of their total amounts. And a similar argument applies to the employment. However, concerning the latter, it is possible to incorporate the standard values for both the total and sectorial employments. As mentioned in the text, this is due to the nonlinear formulation of the sectorial employments, where the aggregative consistency cannot be expected.



† Not required if net increase in stocks and net exports are exogenously given on the sectorial basis.

‡ Not required if sectorial employments are exogenously given.

Figure 5.1. The lineage among the standard values.

regional input-output relation discussed in Section 5.1. Accordingly, the standard values for C1 and C2 are to be determined simultaneously, exactly the same way as we determine their regional values, and in this regard, the actual procedure is a little more complicated than the causal relations depicted in Figure 5.1.

This can be done simply by replacing the regional values, $\tilde{W}$, J, and FM, in eq.(5.4) by their standard values, $\tilde{W}^{o}$, J^{o} and FM^{o}, using an appropriate partition of the itemized net final demand vector W^{o}.

$$X^{o} = [I - (A+CB)]^{-1}[C\tilde{W}^{o} + J^{o} + FM^{o}] \quad (5.4)'$$

Accordingly, the standard values for the value added and its components can be determined from this result. For example, the total value added and the operating surplus in sector i are calculated respectively by $VA^{o} = \Sigma_j a_{0j} X^{o}_j$ and $V^{o}_{40i} = a_{40i} X^{o}_i$. And the former determines the standard values for the private consumption expenditures.[†8]

The rest of the variables, including the sectorial employments, are classified into the third category. The standard value for the manufacturing asset K_i^o is obtained, by definition, from the new investment and the asset inherited from the previous period.

$$K_i^o = (1-\delta_i)(K_{i(-1)}^o - \nabla K_i) + \Delta K_i^o, \qquad (5.27)$$

where ∇K_i is the removal or demolition of assets. It is likely that the standard macro-econometric models would combine the demolition and the depreciation to calculate the capital depreciation rate δ_i, instead of providing a separate sequence of demolitions. In such cases, we might either omit the demolition term in eq.(5.27) or consider the asset K_i as an independent variable. In this regard, the ways to compute each of the standard values would not be unique depending on the availability of those for the other variables.

Finally, it must be noted that our model also expects the major exogenous variables to the model, viz. the regional population and the interest rate, to be provided from an outside model, besides the standard values to the endogenous variables.†9 The latter can be obtained from a national macro model as it can be regarded uniform throughout the nation. On the other hand, the former could be calculated either from an econometric model or a non-econometric one, e.g. the multi-regional cohort model.[9)]

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†8. When the standard values are available for the R-level computation, the term corresponding to $\tilde{W}^o$ in eq.(5.2), which is independent of X, should be replaced by the following expression.

$$\tilde{W}^o = [C1^o(E/E^o) + a_{11}(C1_{-1} - C1_{-1}^o(E/E^o)) - a_{12}VA^o(E/E^o),$$
$$C2^o + a_{21}(C2_{-1} - C2_{-1}^o) - a_{22}VA^o,\ C3,\ \ldots,\ IG]^T.$$

†9. The early version of the model[8)] includes a set of formulas to compute the regional population endogenously. However, those formulas require a number of exogenous variables concerning the rest of the nation. In this regard, the efficient alternatives are either to make the population exogenous or to incorporate models concerning the rest of the nation. Here we choose the former to keep our study area from expanding.

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CHAPTER 6

THE LOCATION MODEL

This chapter is devoted to the formulations in the model block which determines the spatial allocations of stock variables. The model is constructed from five submodels to be executed consecutively in the order of the demolition, basic location, stock accounting, auxiliary location, and the commuting distribution submodels. The aggregate random bid prices play a definitive role in determining the allocation of land among activities. While those bid prices are discriminant in nature, the land prices are calculated posteriorly to summarize the present land use, and to forward information to the demolition in the succeeding period.[1),2)]

6.1. Locating Activities and Land Accounting

6.1.1. Land use categories and locating activities

Until recently, comprehensive data on land use have not been available. Owing to the *National Land Use Planning Law*, which became effective in 1974, the mesh-based land use data were publicized as a part of *National Land Digital Data*. As of the time when our research was conducted, the only available data (KS-200 or KS-202) were for the year 1976, and their categorization focuses mostly on physical land use rather than on socioeconomic aspects.[3)] In particular, the categories of building and miscellaneous lots obtained from the digital data must be subdivided over the industrial and residential activities to meet our model configuration. Incidentally, such data have been compiled in association with the CALUTAS model,[4)] where subdivision is primarily based on the land use maps published by the Geographical Survey Institute available around the year 1977. Accordingly, we recompose these data, furnished by the CALUTAS research group, into the jurisdictional ones, and utilize them as the basis for describing the land use patterns in 1976.[†1]

Concerning the industrial and residential usages, which are hereafter abbreviated as the urban usages, the data obtained above have been classified into nine categories. As we consider six housing types depending on the tenure and building type of each unit, we consider the sum of 41 activities listed in Table 6.1. However, due to the fact that we are interested in urban land use, we might exclude a number of industrial sectors from our land accounting. Sector 01 (Agriculture, forestry and fisheries) is among such sectors since the agricultural land is regarded as a source of land supply to the urban usages and fisheries are mostly operated over the water area. We further exclude Sector 02 (Mining) and the construction sectors from our accounting by the following reasoning. The former, along with forestry belonging to Sector 01, would rarely interfere with the urban

Table 6.1. Classification of locating activities.

CODE	INDUSTRIAL ACTIVITIES	LC	EN	DM	CODE	INDUSTRIAL ACTIVITIES	LC	EN	DM
R 01	Agriculture, forestry and fisheries		E		P 19	Water supply	I	E	U
R 02	Mining		E		P 20	Residential building		E	
R 03	Food and beverages	I	K	M	P 21	Passenger transportation	T	E	T
R 04	Textile	I	K	M	P 22	Freight transportation	T	E	T
R 05	Wooden and paper products	I	K	M	P 23	Communication	C	E	C
R 06	Printing and publishing	I	K	M	P 24	Finance, insurance and real estate	C	E	C
R 07	Chemical products	I	K	M	P 25	Business services	C	E	C
R 08	Metal products	I	K	M	P 26	Entertainment	C	E	C
R 09	Machinery	I	K	M	P 27	Public works of P-level		E	
R 10	Other manufacturing	I	K	M	P 28	Community services of P-level	P	E	P
R 11	Electricity and gas	I	E	U	P 29	Government services of P-level	P	E	P
R 12	Non-residential building		E						
R 13	Far-flung transportation	T	E	T	C 30	Retail	C	E	C
R 14	Wholesale	C	E	C	C 31	Personal services	C	E	C
R 15	Public works of R-level		E		C 32	Public works of C-level		E	
R 16	Community services of R-level	P	E	P	C 33	Community services of C-level	P	E	P
R 17	Government services of R-level	P	E	P	C 34	Government services of C-level	P	E	P
R 18	Clerical business	C	E	C	C 35	Sewage and waste management	I	E	U
CODE	RESIDENTIAL ACTIVITIES	LC	EN	DM	CODE	RESIDENTIAL ACTIVITIES	LC	EN	DM
H1	Single-unit owned houses	R	H	H_1	H4	Multi-unit owned houses	R	H	H_2
H2	Single-unit rented houses	R	H	H_1	H5	Multi-unit rented houses	R	H	H_2
H3	Single-unit issued houses	R	H	H_1	H5	Multi-unit issued houses	R	H	H_2

Notes: 1) LC refers to the land use categories summarized from the mesh-data.
I = Industrial, T = Transportation, C = Commercial, P = Public, and R = Residential usages.
2) EN refers to the location entity; the variable to be primarily distributed.
E = Employees, K = Non-land assets, and H = Housing Units.
3) DM identifies the demolition model to be used for the activity.
M = Manufacturing, T = Transportation, C = Commercial, P = Public, U = Supply and Disposal,
H_1 = Single-unit houses, and H_2 = Multi-unit houses.

†1. As we do not consider C-level zones for the northern three prefectures, the land use data are compiled only for the Southern Kanto Region, comprising Tokyo and the southern three prefectures. The author is grateful to the CALUTAS research group, headed by Prof. Hideo Nakamura of University of Tokyo, for granting permission to access their land use data.

usages since they are mainly operated outside the inhabitable land. And the land use by the latter can be considered to be temporary in the sense that the lot would eventually be transferred to the party who orders the construction.[†2]

Consequently, we consider the remaining 34 activities, which are called the *locating activities*, as to constitute the demand to the urbanized area. To establish the correspondence between these activities and the nine categories mentioned above, further aggregation of the latter appears to be necessary due to the conceptual discrepancies between the physical land use and economic activities. Namely, we re-classify the nine categories into the five categories shown below.

(a) Industrial; industrial, (b) Transportation; trunk line transportation, (c) Commercial; commercial and business, (d) Public; parks and green tracts, education, public and welfare, and (e) Residential; low density detached, high density detached, and mid to high-rise residential areas, where the categories shown to the right of each aggregate category correspond to the ones inherited from the CALUTAS data.

Then we can consider that each locating activity occupies a part of the land designated as one of these five usages as shown in column LC (land use categories) of Table 6.1. In our model, the land occupied by each activity, $L_i(t)$, is first calculated, and the *location entities*, such as manufacturing assets, numbers of employees or housing units, are then distributed in accordance with the allocation of land. Which variable is to be chosen as the entity may depend on the nature of each activity as well as the data availability. The column EN identifies such entities which are regarded as the leading factors in terms of locations. The remaining

†2. It must be noted that under the usual industrial classification, the managerial segments of those sectors are to locate within the urbanized area even though their sites for actual production do not interfere with the other usages. We here disregard such conflicts by virtue of our sectorial definition that sector 18 (Clerical business) is detached from its mother industries.

column (DM) will be referred to later in Section 6.6.

6.1.2. Land accounting and data compilations

One of the objectives in the location model is to determine the zonal land use, and it would be meaningful to clarify the relationship among the relevant variables, both static and transitional. In the model, all the locational transactions are assumed to take place instantaneously at the beginning of each period, and the resulted state is assumed to be maintained throughout the rest of the period.

$L_i(t-1)$ in Table 6.2 denotes the land occupied by the i-th activity in period (t-1), where the superscript c to identify the zone is omitted as there might be no confusion. The possible transactions to attain $L_i(t)$ for the succeeding period are the demolition and the location. When we denote the land released by the former and that acquired by the latter by $\nabla L_i(t)$ and $\Delta L_i(t)$, respectively, we can write

$$L_i(t) = L_i(t-1) - \nabla L_i(t) + \Delta L_i(t), \quad i \in A, \tag{6.1}$$

where A is the set of locating activities. And when we take the summations of respective terms, we will have the urbanized area, $LU(t) = \sum_{i \in A} L_i(t)$, along with its decrement and increment, $\nabla LU(t)$ and $\Delta LU(t)$.

We assume that the urban land use is confined within the inhabitable land, i.e., $LU(t) \leqq LF(t)$ according to our notations. And the non-inhabitable one is considered only in the form of the development of new land, $\Delta LF(t)$, either by leveling mountains or by reclamation.[†3] The difference between the inhabitable land and land actually used for urban

Table 6.2. The land accounting table.

	State in period (t-1)	Locational transactions in period t				State in period t
		Demolition	Ground for location	Location	Development of new land	
(a) Locating activity	$L_i(t-1)$	$\ominus \nabla L_i(t)$		$\oplus \Delta L_i(t)$		$L_i(t)$
(b) Land of urban usages $= \Sigma$ (a)	$LU(t-1)$	$\ominus \sum_i \nabla L_i(t)$		$\oplus \sum_i \Delta L_i(t)$		$LU(t)$
(c) Vacant land	$LA(t-1)$	$\oplus \sum_i \nabla L_i(t)$	$LAD(t)$	$\ominus \sum_i \Delta L_i(t)$	$\oplus \Delta LF(t)$	$LA(t)$
(d) Inhabitable land	$LF(t-1)$				$\oplus \Delta LF(t)$	$LF(t)$

usages is regarded as the vacant land, including the agricultural land. However, the land after demolitions,

$$LAD(t) = LA(t-1) + \sum_{i \in A} \nabla L_i(t), \tag{6.2}$$

may be considered more important than the vacant land representing the state as the former provides the ground for new locations. This stems from the fact that demolitions are assumed to take place at the very beginning of each period as mentioned in Section 2.3. The vacant land can also be calculated by subtracting the land occupied by the new locators from the land after demolitions.

$$LA(t) = LF(t) - LU(t) = LAD(t) - \sum_{i \in A} \Delta L_i(t). \tag{6.3}$$

As the CALUTAS land use data only provide, to our model, the state in 1976 in five categories shown above, we need to subdivide them into 34 locating activities and to extrapolate them annually towards 1980 to facilitate the test simulation. Thus in the following, we discuss the procedures for such estimations.

(a) Industrial land area by sectors in 1976: The sectorial areas are calculated by distributing the area classified to each category in proportion to the sectorial employees belonging to that category. Meanwhile, the land area in manufacturing sectors (03-10) would be consumed mostly to house their manufacturing assets rather than the employees. As the data on land assets are available in *Census of Manufactures*, the land area allocated to these sectors is redistributed basically in accordance with this information.

(b) Residential land area by types in 1976: As the calculations are mainly based on the 1978 *Housing Survey*, the three different treatments become

†3. Like the stochastic considerations, Table 6.2 assumes that development of new lot and location of an activity onto the same lot cannot take place in a single period. As a matter of course, another possible alternative is to assume that such developments take place instantaneously at the very beginning of the period similar to demolitions. However, when we consider the time and money required to such developments, the former might be the better choice.

necessary for three types of jurisdictions classified by data availability. These are i) the cities and wards with populations of more than 50 thousand, ii) other jurisdictions with publicized residential land prices, and iii) 81 townships and villages without such information. The distributions of the residential area over the six housing types are made in accordance with i) the lot sizes per housing unit shown in the Housing Survey, ii) the values of the lot size function, which is explained by the land prices, and iii) the average lot sizes calculated for the jurisdictions with populations of less than 50 thousand, respectively.[5)]

(c) Regression of land area per unit stock to the land prices: As the stocks for which the land-to-stock ratios are calculated, we choose the number of employees for most industrial sectors. However, we employ the land assets for manufacturing sectors, the floor spaces for single-unit houses, and the number of housing units for multi-unit houses instead. For example, suppose L_h and F_h are the land area and floor space assigned to the single-unit houses of type h, respectively. Then the relevant conversion ratio is regressed cross-sectionally in the following manner.

$$L_h/F_h = f_h(VL) = \alpha VL^{-\beta}, \tag{6.4}$$

where the parameter β attached to the land price VL becomes negative for every activity.

(d) Land areas by activity for the succeeding years: We extrapolate the sectorial land areas for 1976 obtained by steps (a) and (b) using the changes in stocks on which the land-to-stock ratios are defined.

i) Set the period $t \leftarrow (t+1)$, and estimate the land area released as a result of demolition of the relevant stock. For example, that for the single-unit houses is obtained by

$$\nabla L_h(t) = (L_h(t-1)/F_h(t-1))\nabla F_h(t),$$

where the term within the parenthesis is the ratio calculated from eq. (6.4).[†4] It must be noted that we must use $-\min\ (E_i(t)-E_i(t-1),0)$ instead of $\nabla E_i(t)$ if the relevant stock is the number of employees, since the net changes are the only information we can obtain regarding the employees. The ground for new locations can then be calculated through eq.(6.2).

ii) Calculate the land acquisition for the present period using the land-to-stock ratio. In the case of the single-unit houses, we may use $\Delta L_h(t) = \alpha \Delta F_h(t) VL(t)^{\beta}$, and the similar argument as above applies to the case where the numbers of employees are considered as the net of ratios. When the sum of areas newly acquired violates the physical constraint,

$$\sum_{i \in A} \Delta L_i(t) \leq LAD, \tag{6.5}$$

the estimates will be determined by reducing $\Delta L_i(t)$ proportionately so that eq.(6.5) is satisfied in equality. Finally, we calculate the land areas by activity and the vacant land through eqs.(6.1) and (6.3), respectively, before returning to step i).

6.2. The Basic Location Submodel

6.2.1. Relevant activities and the bid price function

As Figure 3.1 illustrates, the execution of the location model initiates in the demolition submodel, which determines the amount of land available to the new locators, and the present submodel comes next to it. On the ground of its significance, however, the latter submodel plays the key role in determining the spatial allocation of activities, and this prompts us to start our model description from there. The model allocates activities over the study area in the way that the land acquisition ΔL_i^c of the i-th activity in zone c is first calculated, and the location entities are then allocated in accordance with these acquisitions.

The activities to be allocated through the present submodel are the *locating activities* as defined in the previous section. That is, those

†4. As a matter of course, there exists no guarantee that the stocks with the average land-to-stock ratio are demolished. In reality, the stocks which utilize the land less efficiently are likely to be demolished. Nevertheless we here calculate the areas released by demolitions using the ratios for the previous year since it is statistically impossible to trace the history of stocks.

activities which are identified by some symbol, either I, T, C, P or R corresponding to what category the land occupied by the activity is to be classified, in column LC in Table 6.1. Hence, it must be noted that the word "basic" is used in the different context from the "basic sectors" in the Lowry model.[6)] Namely, it simply illustrates the importance of the outputs from this submodel in the sense that the outline of land use for each period is basically determined there.

According to the discussion in Section 2.2, we employ the random bid price theory, rather than the random utility theory, as the basic scheme to describe the locational competition in our model.[†5] In other words, the location probabilities are calculated from the viewpoint to determine how to allocate the land among activities in each zone. Unlike the probabilities based on the latter, no specific readjustment procedures are required with the former as the land is thoroughly allocated among activities when we explicitly consider the reservation demands. On the other hand, it is possible to consider such probabilities either in terms of stocks or of stock increases. While the latter is theoretically desirable for describing locational dynamism, we here combine these two probabilities, as a consequence of the discussion in Section 2.3, in the way that the former is employed for parameter estimations and the latter for actual simulations.

We consider those bid prices in the aggregative context since the simulation model to be proposed through this study is aggregative by nature. Accordingly, the location probability that $\rho_i^c \times 100\%$ of the parcels of land in zone c are occupied by the i-th activity is defined by an expression equivalent to eq.(2.2),

†5. Miyamoto[7)] proposes a model which tries to bring both random utilities and random bid prices into an equilibrium. However, as far as the utilities considered in the former are indirect, they only represent the revealed preferences under an equilibrium. It must be noted, in this connection, that a combination of both approaches would provide essentially no additional information on the locational behavior.

$$\rho_i^c = \frac{L_i^c}{\sum_{j \in \tilde{A}} L_j^c} = \frac{\exp \Psi_i^c}{\sum_{j \in \tilde{A}} \exp \Psi_j^c}, \tag{6.6}$$

where $\tilde{A}$ is defined as an augmented set of activity codes which incorporates the reservation demand (j=0) to that of locating activities A. In practice, the denominator of the second term is regarded as being equal to the inhabitable land LF^c, and thus, the land reserved is given by

$$L_o^c = LF^c - \sum_{j \in A} L_j^c.$$

Although it is possible to consider various functional forms including the hedonic type ones,[8)] we here consider the one formulated as a linear combination of various potentials as the bid price function Ψ_i^c. That is, when we denote the k-th potential variable in zone c employed for the i-th activity by X_{ik}^c, Ψ_i^c is given by the following formula.

$$\Psi_i^c = \alpha_{io} + \Sigma_k \alpha_{ik} X_{ik}^c, \tag{6.7}$$

where α_{io} and α_{ik} are the constant and the parameters to be estimated.

6.2.2. The distance measures

To calculate the potentials, the most important task is to determine the distances among zones. In this study, we consider the distances by two modes, $TF^{cc'}$ by car and $TM^{cc'}$ by public transports primarily by rail, where both are evaluated in terms of standard trip times in minutes. The former is intended to the use in conjunction with the potentials regarding industrial activities except for those supposed to express the human interactions, to which the latter is applicable. And the use of two kinds of distances mandates us to construct the road and railroad networks linking the zones, which are shown in Figures 6.1 and 6.2, respectively.[†6]

†6. The former has been constructed from the road maps available in 1985, which primarily reflect the network around 1983, and the latter is based upon the train timetables published in 1980. It must be noted that the physical information is not enough to build the latter as it must reflect the actual schedule of train operations such as the express services. The author would like to thank Messrs. Hiroyuki Nitta and Hiroshi Yamada, the former students at Kyoto University, for their assistance in constructing the road and railroad networks.

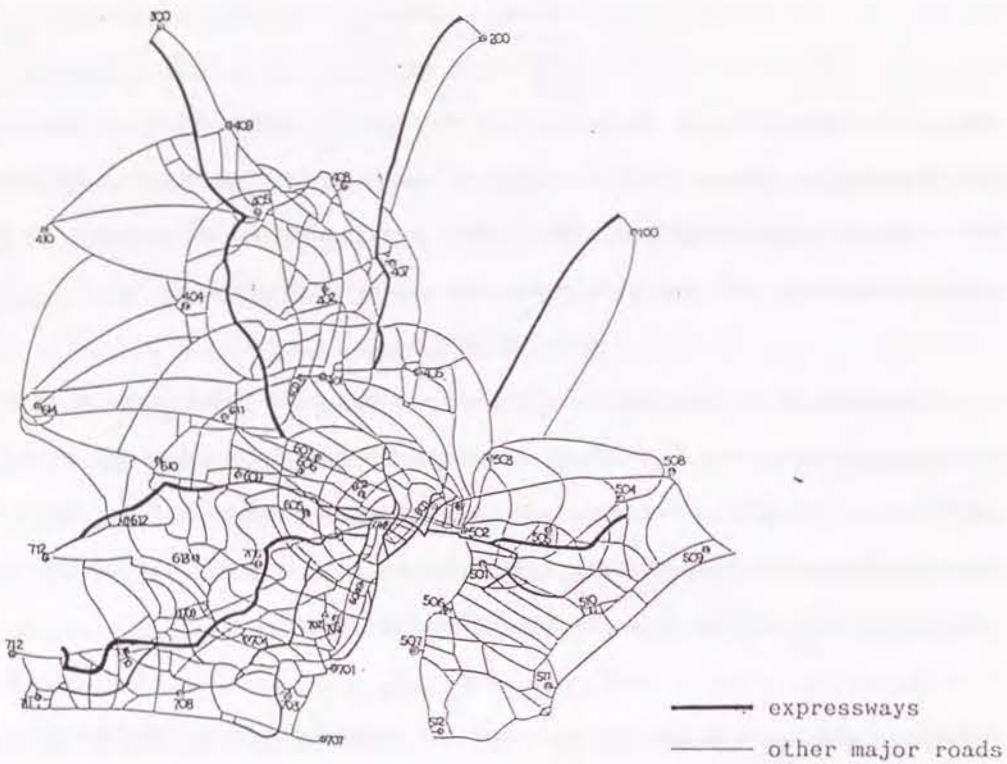

Figure 6.1. The road network (ca.1983).

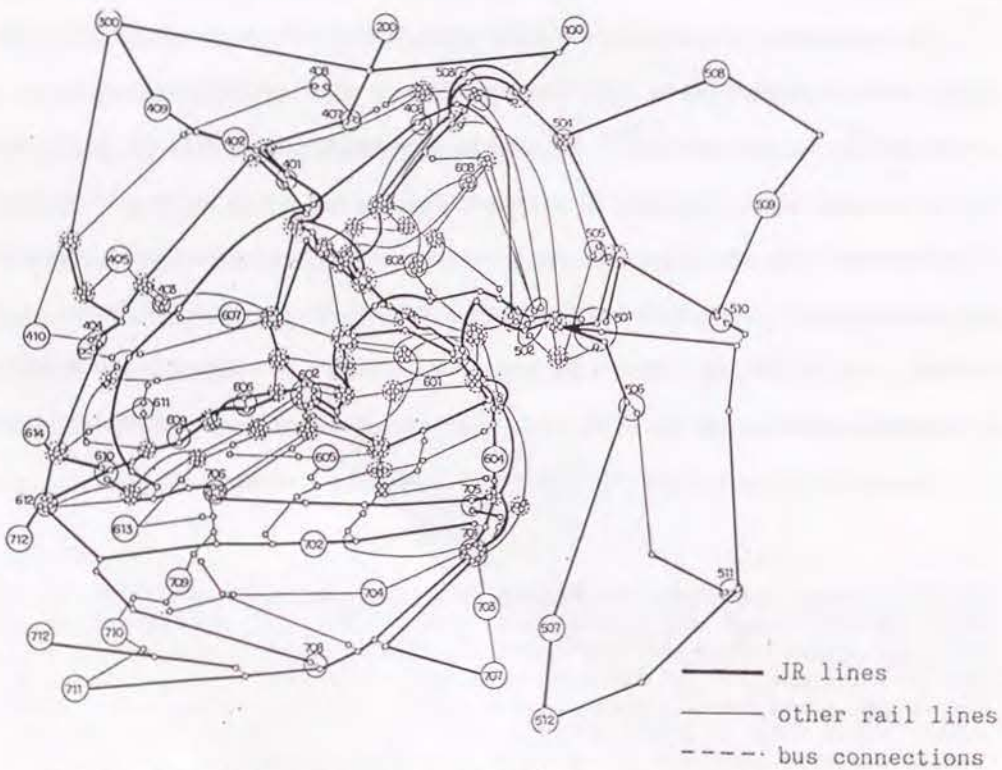

Figure 6.2. The railroad network (1980).

Concerning the railroad network, the centroid of each zone is placed at a station or two as listed in Table 3.1. Those are selected from the major stations in the municipality or the ward which are either prominent in the zone or located near the geographical center of the zone if we cannot select one municipality (ward) as being prominent. The centroids in the road network are placed, with a few exceptions, at the city halls (or ward offices) where such stations are located. Concerning the northern three prefectures, which do not receive further subdivisions, their centroids are placed either at the prefectural government offices or at the major stations of the municipalities where these offices are located. On the other hand, the centroids for the P-level zones of Tokyo and the rest of the prefectures are defined as to coincide with those of the C-level zones where the respective prefectural government offices are located.

Once the networks are constructed, the shortest distances among the zones can easily be calculated through the Dijkstra's method.[9)][†7] However, one question always associated with such distances is how to determine the intrazonal ones. Here we regard an intrazonal distance as being approximated by a third of the average distance to the zones which share the border with the zone concerned. This may be justified as follows.[10)]

Suppose there exists a line segment of length 2r, and the trip generation and absorption take place in accordance with the uniform probability density c=1/2r over the segment, where the value of c is determined from the expression; $\int_{-r}^{r} c\,d\rho = [c\rho]_{-r}^{r} = 2cr = 1$. Then we can calculate the average trip length t(s) along the segment given a destination point s by

$$
\begin{aligned}
t(s) &= (1/2r)\int_{-r}^{r}|\rho-s|\,d\rho \\
&= (1/2r)\int_{s}^{r}(\rho-s)\,d\rho + (1/2r)\int_{-r}^{s}(s-\rho)\,d\rho \\
&= (1/4r)[(r-s)^2+(r+s)^2] = (1/2r)(r^2+s^2).
\end{aligned}
$$

†7. Two central townships, Yamakita and Sagamiko, are chosen for Zone 712 where the Tanzawa mountains lie at the middle of the zone. Accordingly, the shortest distances to and from this zone is defined as the minimum of either distances concerning these two centroids.

And the average trip length T over the segment becomes

$$T = (1/2r)\int_{-r}^{r}(1/2r)(r^2+ s^2)ds = (2/3)r.$$

As the average distance R from a zone center to the centers of the adjacent zones might be interpreted as the twice of the hypothetical radius of the zone concerned, R/3 would provide the average trip length therein. It must be noted, however, that this convention is applicable only when the zone can be approximated by a line segment, and the activities are distributed rather uniformly over it. In other words, in the real-world zones where the activities are biased, R/3 is likely to overestimate the real averages.[†8]

The road and railroad time distances employed in the study are summarized as Tables A.3 and A.4 in Appendix, respectively.

6.2.3. The potential variables

In the *activity model* described in Chapter 4, the distributions are made in two phases; viz. from the Region to the prefectures and from the prefectures to the zones. However, the location model entails the distributions in a single phase, and thus, those potentials should be calculated as the integrations concerning the C-level zones.[†9] More precisely, the following seventeen potentials are regarded as the candidates in the study.

1) Intermediate inputs *XS*: $\Sigma_{c'}\Sigma_{j=1}^{35}a_{ji}X_{j(-1)}^{c'}\exp(-\beta_i TF^{c'c})$,

†8. There might be an argument on whether to predetermine the centroids irrespective of activity distributions. Namely, there is an alternative to calculate those centroids as the gravity centers of the actual zones. However, when we try to predict the future locations of activities, the latter approach may be misleading in the sense that the distances perceived by the new locators would not necessarily coincide with those by the existing ones as the gravity centers tend to lie amidst the built-up areas. Likewise it might not be worthwhile to elaborate on calculating the intrazonal distances from the actual trip observations as they also reflect the transactions among the existing locators.

†9. As discussed in Section 3.1, no subdivisions are introduced to the northern three prefectures. Consequently, those prefectures as a whole are regarded as single zones, equal to the other 48 C-level zones, when calculating those integrations, even though the former are generally accompanied by variables of greater magnitudes than the latter.

2) Intermediate demands *AX*: $\Sigma_{c'}\Sigma_{j=1}^{35}a_{ij}X_{j(-1)}^{c'}\exp(-\beta_i TF^{cc'})$,

3) Net final demands *Y*: $\Sigma_{c'}\tilde{Y}_{i(-1)}^{c'}\exp(-\beta_i TF^{cc'})$,

4) Net demands *AX+Y*: defined as the sum of 2) and 3) above,

5) Values added *VA*: $\Sigma_{c'}VA_{-1}^{c'}\exp(-\beta_i TF^{cc'})$,

6) Population *N*: $\Sigma_{c'}N_{-1}^{c'}\exp(-\beta_i TM^{cc'})$,

7) Total employees *E*: $\Sigma_{c'}E_{-1}^{c'}\exp(-\beta_i TM^{cc'})$,

8) Urban employees, for those sectors designated as the urban activities shown in Table 3.2, *EU*: $\Sigma_{c'}EU_{-1}^{c'}\exp(-\beta_i TM^{cc'})$,

9) Non-urban employees, viz. those employed by Sectors 1 and 2, *EA*: $\Sigma_{c'}(E_{1(-1)}^{c'}+E_{2(-1)}^{c'})\exp(-\beta_i TM^{cc'})$,

10) Employees in Sector 17 (Government services of R-level) E_{17}: $\Sigma_{c'}E_{17(-1)}^{c'}\exp(-\beta_i TM^{cc'})$,

11) Employees in Sector 18 (Clerical business) E_{18}: $\Sigma_{c'}E_{18(-1)}^{c'}\exp(-\beta_i TM^{cc'})$,

12) Employees in Sectors 17 and 18 combined E_{17+18}: defined as the sum of 10) and 11) above,

13) Employees in Sectors 17 and 29 (Government services of R and P-levels) *EMRP*: $\Sigma_{c'}(E_{17(-1)}^{c'}+E_{29(-1)}^{c'})\exp(-\beta_i TM^{cc'})$,

14) Employees in Sectors 16 and 28 (Community services of R and P-levels) *EPRP*: $\Sigma_{c'}(E_{16(-1)}^{c'}+E_{28(-1)}^{c'})\exp(-\beta_i TM^{cc'})$,

15) Employees in Sector 33 (Community services of C-level) E_{33}: $\Sigma_{c'}E_{33(-1)}^{c'}\exp(-\beta_i TM^{cc'})$,

16) Employees in community services of all levels *EP*: defined as the sum of 14) and 15) above, and

17) The accessibility to the nearest port *TP*: $\exp(-\beta_i TP^{c})$.

Here X_i^c, $\tilde{Y}_i^c$ and E_i^c are the production of, the net final demand to, and the number of employees of the i-th sector in zone c, respectively.[†10] In contrast to the potentials 5) through 16), which are common to all sectors, those from 1) to 4) are defined for respective sectors and mostly based upon the input coefficients, a_{ij}, which are assumed to be common throughout the Region. β_i is the distance decay ratio attached to the distances,†11 and the last one is defined as a simple accessibility measure depending on the time distance by car to the nearest port TP^c from each zone.†12

As shown in eq.(6.7), the bid price functions in our model are to be defined by combining some of the above potentials. However, the number of such functions to be determined simultaneously through eq.(6.6) reaches 35 including the one for the reservational uses. Even if we limit the number of potentials contained in each bid price function to two, the number of parameters to be estimated amounts to 140. And it is virtually impossible to estimate thus many parameters simultaneously particularly when the equations to be estimated are nonlinear. Hence, some kind of convention must be introduced to estimate those parameters, and this will be the focal point in the next subsection.

6.2.4. The estimation procedure

As eq.(6.6) is essentially multiplicative, it is possible to estimate the parameters α_{ik}, which linearly reflect upon the bid price function, through log-linear regressions. By taking the logarithms of eq.(6.6),

†10. As mentioned in Footnote 7 of Chapter 4, the macro variables with monetary denominations, such as X_i, Y_i, VA, and the industrial assets K_i, are in million yen, and the population N and the number of employees E_i are given in persons. Meanwhile, the area variables such as L_i and LF are in hectares, and the land prices VL are given in hundred yen per square meter.

†11. It is theoretically desirable to separately assign a decay ratio to each potential term associated with a single sector. However, in practice, the estimation method confines us to applying a common ratio to all the terms in a sector as to be discussed in the next subsection.

†12. Here the ports are limited to the *major ports* including the specially designated ones as defined by the regulations associated with the *Port and Harbor Law*. Those relevant to our study area are Kashima, Hitachi, Oarai and Naka in Ibaraki Pref., Chiba and Kisarazu in Chiba Pref., Keihin spanning across the border between Tokyo and Kanagawa, and Yokosuka in Kanagawa Pref. Among them, Chiba and Keihin are the specially designated ones. For convenience sake, the distances to the ports are assumed to be equal to those to the centroids of zones where respective ports are located.

$$\log \rho_i = \Psi_i - \log \Sigma_{j \in \tilde{A}} \exp(\Psi_j),$$

where the zone identifiers c are omitted for simplicity. According to the Berkson's method,[11)] the log-sum variable in the above expression can be eliminated by arbitrarily regarding one of the functions as the reference. Suppose the one corresponding to the reservational uses (i=0) is employed as the reference. Then we have

$$\log \rho_i - \log \rho_o = \Psi_i - \Psi_o. \qquad (6.8)$$

When all the bid price functions Ψ_i ($i \neq 0$) are linear and explained by a common set of variables, a simple log-linear regression may enable us to determine the bid price functions independently of other activities. However, the second requirement can hardly be accepted particularly when the alternatives are the activities rather than the zones. And even when we accept such restrictive formulations, there would still remain an identification problem[12)] concerning the reference bid price function Ψ_o unless the reservational uses are assumed to play no active role, viz. $\Psi_o \equiv 0$. On the contrary, we here assume that those uses would also claim some bid price to surrender the land, and this makes the expressions for all the locating activities be interconnected through Ψ_o. In addition, as each bid price function includes a distance decay parameter β_i, the expression as a whole becomes nonlinear by nature. Accordingly, even with the log-linear convention, the procedure to estimate all the parameters associated with eq.(6.8) would become a simultaneous nonlinear regression in the sense that the parameters relevant to Ψ_o must be determined simultaneously across all of the 34 renditions of eq.(6.8), and each expression is subject to a nonlinear regression.

From the dynamic theory of land use, the reservational land price P at the turning point in terms of the landowner's portfolio, whether to sell the lot, is given by $P = \dot{P}/\gamma$ provided that the discount rate is fixed at γ.[13)] Since such an expression is unstable with the change in the discount rate, it would be practically necessary to introduce the land price in the previous period VL^c_{-1}, which may be regarded as the price quoted for such transactions, to the reservational bid price. Then

$$\Psi^c_o = \lambda_o VL^c_{-1} + \lambda_1 (\Delta VL^{c*}/\gamma)$$

might serve as its candidate, where ΔVL^{c*} denotes the expected increase in the land price. Alternatively, when we assume that the discount rate to the land price depends on the scarcity of land, as being represented by the inhabitable land LF^c, we might have another candidate,

$$\Psi^c_o = \lambda_o VL^c_{-1} (LF^c)^{-\lambda_1}.$$

However, as none of these expressions are successful in bringing the significant parameter estimates, we simply assume that the reservational bid price is proportional to VL^c_{-1}, viz.

$$\Psi^c_o = \lambda VL_{-1}. \tag{6.9}$$

Given the parameter λ contained in eq.(6.9) and the distance decay parameters β_i, the remaining linear parameters α_{ik} can be determined through the individualistic log-linear regressions for respective activities. Accordingly, it is possible to determine all the parameters relevant to eq.(6.6) through an iterative procedure summarized below.

o) Arbitrarily determine the initial values of β_i and λ.

i) Given these β_i and λ, calculate the linear parameters α_{ik} log-linearly from eq.(6.8), and obtain the error associated with the j-th observation.

$$r_{ij} = (\log \rho_i - \log \rho_o + \Psi_o(\lambda)) - \Psi_i(\alpha_i | \beta_i),$$

where α_i is a vector consisting of the linear parameters.

ii) Solve the unconstrained nonlinear minimization problem concerning the sum of squared errors (SSE),

$$\min_{\beta_i, \lambda} SSE = r'r, \tag{6.10}$$

where r is the column vector of r_{ij} based on α_{ik}.

iii) Repeat steps i) and ii) until the convergence criterion for the nonlinear parameters, β_i and λ, is met.

In the present study, the number of observations may differ across the activities, $i = 1, \ldots, m$, due to the data limitations; the full set of

data corresponding to the manufacturing sector have been compiled for Tokyo and two prefectures facing Tokyo Bay, for instance. Thus the dimension of the error vector r is ruled by the number of effective observations n_i.

$$r' = (r_{11}, \ldots, r_{1n_1} | r_{21}, \ldots, r_{2n_2} | \ldots | r_{m1}, \ldots, r_{mn_m}),$$

Meanwhile, the problem (6.10) corresponds to the OLS estimation in the case of nonlinear simultaneous regressions. In general, it is possible to use a quadratic form, $SSE = r'Wr$ based on an appropriate weight matrix W, instead. However, there will be another question as to how such weights can be determined in practice.†13

Despite its simultaneous nature, only a weak interdependency across the activities can be found in the problem (6.10) in the sense that each activity is merely interconnected through the parameter λ of the reservational bid price. Taking advantage of this observation, the variables relevant to each activity are selected independently with the nonlinear parameters determined in (6.10) being fixed. Selection procedure is based on the nonlinear regressions for all the meaningful combinations of three variables or less drawn from the variable pool comprising the 17 variables listed in the previous subsection, where the following rules are employed to determine the actual bid price functions.

i) To qualify as a candidate function, all of its parameters must satisfy the sign requirements, which are deduced from the economic implications, and be found significant at the 10 % level. Among those candidates, the one which demonstrates the highest R-square would be the primal choice.

ii) If the model containing $AX+Y$ as one of the variables is acceptable, it may become the choice provided that the differences in R-squares are less than 1 % as compared with those containing either AX or Y instead.

iii) In non-manufacturing sectors other than Sector 13 (Far-flung

---

†13. There are some alternative ways to determine the weight matrix P. For example, the procedure SYSNLIN in the statistical package SAS/ETS prepares a number of options for this purpose (see Table 21.2 in the procedure description).[14)]

transportation), the model must reflect one of such potentials, viz. *AX*, *Y*, *AX+Y*, *VA*, *N*, *E*, or *EU*, that can be regarded to represent the demand-side requirements to some extent.

iv) The potential E_{33} will not be used to explain locations of the R-level activities. For the P-level activities, the model containing *EP* will be chosen when the difference in the R-squares between the models containing E_{33} and *EP* is less than 1 %.

v) Regarding the local activities other than those classified as transport-communication or supply-dispose industries, the port accessibility *TP* is precluded from our consideration.

vi) The potential E_{17} will not be used in conjunction with the C-level and residential activities.

6.2.5. Estimated bid price functions

The models finally selected through the above rules are summarized in Table 6.3, including the variables chosen, the parameters and their t-values, the R-squares for the log-linear regressions (6.8), along with the distance decay ratios and their asymptotic t-values.†14 As the reservational bid price, we have

$$\bar{r}^{c}_{o} = -.0002279VL^{c}_{-1}, \quad (6.9)'$$
$$(7.88)$$

where VL^{c}_{-1} is calculated as the posterior land price based on the population and employment densities as to be discussed in Section 6.6. It might be felt somewhat strange that the reservational bid price becomes negative.

†14. Regarding the manufacturing census data, the rough estimations have only been compiled for the C-level zones in Saitama Pref. Accordingly, the computations are based upon 190 observations (38 zones over five years) in the manufacturing sectors (03-10). In addition, as the land use data are not available in Zone 410 (Chichibu) except for transport and residential uses, the results for the non-transport and non-residential activities are based upon 235 observations (47 zones over five years). The full set of data with 240 observations have been available only to Sectors 13, 21 and 22 along with the residential locators (H1-H6).

The nonlinear least squares problem (6.10) has been solved through a Fortran SSL package program called DMINF1, which is based upon the quasi-Newton method.[15)]

Table 6.3. The parameters of the bid price functions.

Legend:

	Kind of potentials X_{ik}	Linear R^2 (degrees of freedom)
Intercepts α_{i0} t-values	Parameters α_{ik} t-values	distance decay parameters β_i asymptotic t-values for β_i

03	Food/beverages -7.3880 45.58	TP 2.0340 4.00	N $.5452*10^{-6}$ 7.32		R^2=.6226(187) β=.03864 10.41
04	Textile -9.5259 42.49	XS $.2490*10^{-5}$ 3.24	N $.2267*10^{-6}$ 2.41		.4864(187) .02707 6.04
05	Wooden/paper -8.3768 46.20	XS $.2312*10^{-5}$ 6.42	TP 2.4408 4.99		.6000(187) .02600 3.54
06	Printing/publishing -10.136 58.69	AX+Y $.2726*10^{-5}$ 2.33	TP 1.5515 2.39	E_{17} $.9855*10^{-4}$ 6.43	.7621(186) .04390 22.44
07	Chemical -6.8838 38.97	TP 5.7070 9.97			.3864(188) .05924 16.37
08	Metal -8.7746 31.29	TP 6.8076 14.53			.5569(188) .01787 6.34
09	Machinery -7.3349 29.74	AX $.1220*10^{-5}$ 6.63	TP 2.7177 4.64		.5686(187) .02139 7.07
10	Other Manufact. -7.4052 38.36	AX+Y $.1176*10^{-5}$ 4.63	TP 2.6796 5.48		.5188(187) .02553 4.60
11	Electricity/gas -9.3699 76.39	TP 4.3866 9.84	N $.3960*10^{-6}$ 4.45		.6590(232) .05076 11.11
13	Far-flung transp. -7.4377 69.84	TP 2.2903 4.93	$\lvert E_{17}\rvert$ $.9679*10^{-4}$ 13.07		.7698(237) .04725 17.68
14	Wholesale -7.9385 94.31	Y $.1935*10^{-4}$ 8.22	TP 3.2908 5.30	E_{17} $.1378*10^{-3}$ 6.48	.8341(231) .10613 20.32
16	R-Community sces. -6.5006 66.59	AX $.1022*10^{-3}$ 8.18	E_{17} $.8796*10^{-4}$ 8.73		.7884(232) .06749 21.66
17	R-Gov't sces. -6.0348 61.30	Y $.3996*10^{-5}$ 1.97	TP 1.5711 2.99	EMRP $.6341*10^{-4}$ 6.55	.7327(231) .06990 10.61
18	Clerical -7.6487 78.29	AX $.3001*10^{-5}$ 5.68	TP 1.0053 2.19	E_{17} $.7568*10^{-4}$ 6.45	.8164(231) .05255 14.42
19	Water supply -9.0328 79.84	TP 4.6911 9.83	N $.4557*10^{-6}$ 3.81		.6416(232) .06405 11.13
21	Passenger transp. -7.0701 63.06	TP 1.6975 4.15	VA $.5636*10^{-7}$ 1.98	E_{17} $.7109*10^{-4}$ 8.40	.8021(236) .03628 9.63
22	Freight transp. -6.4559 59.78	Y $.1543*10^{-4}$ 2.28	TP 2.0596 5.18	E_{17} $.6319*10^{-4}$ 7.60	.7854(236) .04008 8.27
23	Communication -9.3399 106.2	Y $.4177*10^{-4}$ 4.80	TP 1.1882 2.49	E_{17} $.1284*10^{-3}$ 9.12	R^2=.8192(231) β=.07466 11.91
24	Finance/real estate -8.5409 87.31	Y $.3032*10^{-5}$ 5.85	E_{17} $.1362*10^{-3}$ 14.25		.8344(232) .06156 13.11
25	Business sces. -8.0436 86.77	XS $.3540*10^{-5}$ 3.98	Y $.3578*10^{-4}$ 2.67	E_{17} $.1131*10^{-3}$ 9.60	.8313(231) .06373 12.96
26	Entertainment -9.3469 106.7	AX $.2620*10^{-4}$ 4.91	E_{17} $.1090*10^{-3}$ 9.52		.8143(232) .05943 12.28
28	P-Community sces. -5.0456 64.39	AX $.1992*10^{-4}$ 3.51	E_{17} $.9134*10^{-4}$ 8.16		.7460(232) .06717 6.68
29	P-Gov't sces. -6.2056 63.10	VA $.3125*10^{-6}$ 3.59	EMRP $.8269*10^{-4}$ 6.06		.6870(232) .09034 11.88
30	Retail -6.9438 75.33	VA $.1943*10^{-6}$ 5.31	EMRP $.4229*10^{-4}$ 7.27		.7833(232) .05130 8.70
31	Personal sces. -7.7164 82.28	VA $.1998*10^{-6}$ 5.74	EMRP $.4665*10^{-4}$ 8.42		.8170(232) .04883 8.63
33	C-community sces. -4.6131 53.03	VA $.1244*10^{-6}$ 3.56	EMRP $.4399*10^{-4}$ 7.92		.7593(232) .05178 6.92
34	C-Gov't sces. -5.6955 63.80	VA $.5166*10^{-7}$ 1.73	EMRP $.3381*10^{-4}$ 7.12		.6692(232) .04509 6.44
35	Sewage/waste -8.4244 73.76	AX $.2854*10^{-4}$ 2.28	TP 3.4610 8.06	N $.3797*10^{-6}$ 3.34	.6727(231) .05313 10.43
H1	Single/owned -3.0779 36.84	VA $.7930*10^{-7}$ 2.86	E_{33} $.1938*10^{-4}$ 7.01		.7232(237) .04446 6.96
H2	Single/rented -6.9013 54.48	VA $.6890*10^{-7}$ 3.12	EP $.1024*10^{-4}$ 8.20		.7647(237) .02525 7.77
H3	Single/issued -8.0491 67.79	VA $.5912*10^{-7}$ 2.03	EPRP $.3884*10^{-4}$ 9.15		.7445(237) .03562 7.07
H4	Multiple/owned -9.1785 61.60	VA $.1055*10^{-6}$ 3.63	EPRP $.3920*10^{-4}$ 9.42		.7908(237) .02896 7.56
H5	Multiple/rented -9.9201 53.50	VA $.1011*10^{-6}$ 3.59	EPRP $.4201*10^{-4}$ 10.62		.8172(237) .02271 7.68
H6	Multiple/issued -10.388 57.03	EMRP $.5993*10^{-4}$ 26.43			.7724(238) .02395 6.61

This relates to the discriminant nature of the bid prices in our study, where an activity must present a higher bid in order to occupy a larger portion of land. Namely, the share of the agricultural land tends to be lower wherever the higher land prices are observed.[†15]

As discussed in Chapter 2, it is possible to calculate the shift parameters B^c in eq.(2.3) to make these discriminant bid land prices compatible with the land prices observed. Figure 6.3 summarizes the relationship between the adjusted bid prices, $\Phi_i^c \equiv \Psi_i^c + B^c$, and the location probabilities ρ_i^c. The horizontal and vertical line segments represent the twice of the standard deviations of $\Phi_i^c - VL^c$ and ρ_i^c, respectively, calculated from the pooled data for 47 zones over 5 years, and their intersections are placed to indicate their pooling averages. We can easily confirm from the figure that these two averages are positively correlated.

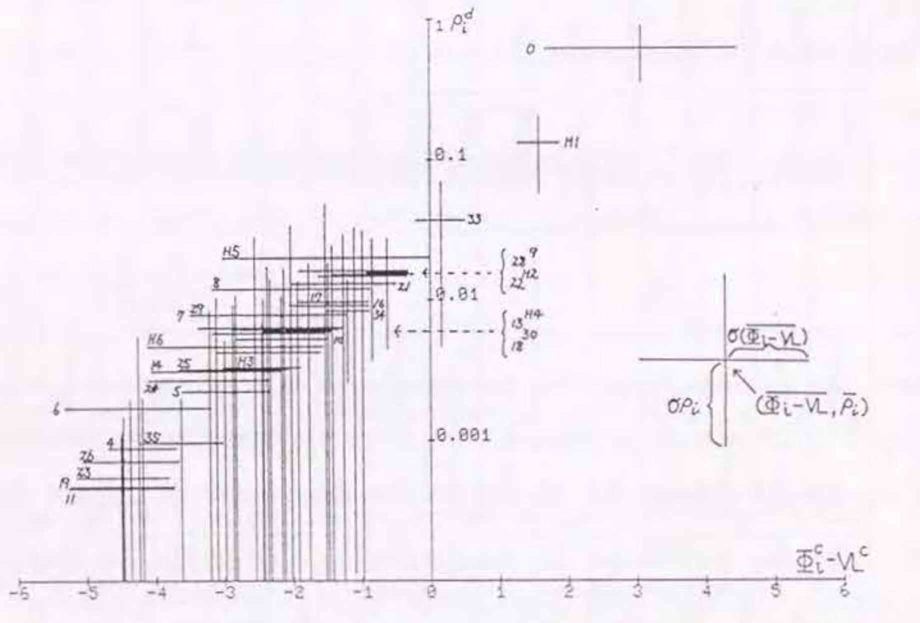

Figure 6.3. Adjusted bid prices Φ_i and locational probabilities ρ_i.

†15. These arguments are based upon eq.(2.1) which is derived from the IIGD hypothesis. However, it might be possible to make the activity with a lower average bid price outbid the ones with higher averages when we employ a Generalized Extreme Value (GEV) model with diversified variance parameters.[16)]

In particular, since agricultural land still prevails in the Southern Kanto Region as a whole with $\bar{\rho}_o = 0.6190$, its bid price dominates the average land price VL^c in most zones. Similarly, H1 (Single-unit owned houses) represents the highest bid prices among urban activities with its ubiquitous nature, which is followed by Sector 33 (Community services of C-level). This can be seen from the fact that the services provided by the latter sector, such as elementary schools, must exist in every community regardless of land prices. On the contrary, the sectors which might be expected to present higher bids, such as Sector 18 (Clerical business), tend to present the modest ones on the average. As a matter of fact, their bids to the parcels they locate would be among the highest, but this does not necessarily imply that they could present higher bids to the aggregative zones since the lots suitable to their locations are rather limited.

6.2.6. Non-land stock increments

Once the bid price functions are estimated, we can calculate the land acquired by each activity ΔL_i^c from eq.(2.7b) along with the land reserved for the non-urban usages L_o^c.

$$\Delta L_i^c = r_i^c LAD^c \quad \text{and} \quad L_o^c \equiv LA^c = r_o^c LAD^c. \tag{6.11}$$

Then the next task is to calculate the location entities attached to the land acquired. As mentioned in Section 6.1, such entities are the increases in assets for manufacturing sectors, and the housing units to be built for residential ones. While the number of employees are regarded as the entities in the rest of the sectors, the employment in an activity may easily fluctuate with the economic circumstances even if there is no change in the amount of land occupied by that activity. And this is the reason why we recalculate the entire employments in the stock accounting submodel to be discussed in the next section.

The zonal increases in manufacturing assets ΔK_i^c are calculated by distributing their regional values ΔK_i determined through eq.(5.9) in the regional frame model. Such distributions are made in accordance with the values of the linear regression formulas, whose explanatory variables are chosen from the land acquired ΔL_i^c, the expected asset increase based on the past records, $(K_{i(-1)}^c / L_{i(-1)}^c)\Delta L_i^c$, the investments to maintain the existing assets after depreciations and demolitions, $(1-\delta_i)(K_{i(-1)}^c - \nabla K_i^c)$, or the term representing Jorgenson's optimal asset, $V_{40i(-1)}^c/(\gamma+\delta_i)$. That is,

$$\Delta \hat{K}_i^c = f(\Delta L_i^c,\ (K_{i(-1)}^c / L_{i(-1)}^c)\Delta L_i^c,\ (1-\delta_i)(K_{i(-1)}^c - \nabla K_i^c),\ V_{40i(-1)}^c/(\gamma+\delta_i)), \tag{6.12}$$

for example, where δ_i is the capital depreciation rate and ∇K_i^c is the amount of assets removed. Here again the hats indicate that those variables are to provide information for zonal distributions, or used as the *distributive measures*. The zonal values are then calculated by

$$\Delta K_i^c = (\Delta \hat{K}_i^c / \Sigma_c \Delta \hat{K}_i^c)\Delta K_i. \tag{6.13}$$

Table 6.4 summarizes the estimated results for the functions to provide the distributive measures for manufacturing sectors. The fact that the land acquisition over the two-year period $(\Delta L_i^c + \Delta L_{i(-1)}^c)$ replaces ΔL_i^c in

Table 6.4. The parameters for the manufacturing asset increments.

03 Food and beverages -146.72 1.11	$(\Delta L_i^c+\Delta L_{i(-1)}^c)$ 147.50 10.08	$(1-\delta_i)(K_{i(-1)}^c-\nabla K_i^c)$ .09773 4.39	$V_{40i(-1)}^c/(\gamma+\delta_i)$ .01972 2.42	$\bar{R}^2$=.8739 (df=110)
04 Textile 53.644 4.15	ΔL_i^c 41.703 3.66	$(1-\delta_i)(K_{i(-1)}^c-\nabla K_i^c)$ .09936 5.66	$V_{40i(-1)}^c/(\gamma+\delta_i)$ .03236 3.00	.7403 (149)
05 Wooden and paper products 123.23 3.52	$(K_{i(-1)}^c/L_{i(-1)}^c)\Delta L_i^c$ .29018 2.89	$(1-\delta_i)(K_{i(-1)}^c-\nabla K_i^c)$ .14784 19.57		.8154 (149)
06 Printing and publishing -155.62 0.61	ΔL_i^c 363.08 3.00	$V_{40i(-1)}^c/(\gamma+\delta_i)$ .04940 12.92		.7407 (149)
07 Chemical products 464.20 1.06	$(K_{i(-1)}^c/L_{i(-1)}^c)(\Delta L_i^c+\Delta L_{i(-1)}^c)$ .17003 3.46	$(1-\delta_i)(K_{i(-1)}^c-\nabla K_i^c)$ .12929 14.20		.8588 (111)
08 Metal products 27.217 0.01	$(\Delta L_i^c+\Delta L_{i(-1)}^c)$ 113.93 3.74	$(1-\delta_i)(K_{i(-1)}^c-\nabla K_i^c)$ .13250 5.73		.4201 (111)
09 Machinery -125.53 0.17	$(K_{i(-1)}^c/L_{i(-1)}^c)(\Delta L_i^c+\Delta L_{i(-1)}^c)$ .45019 5.81	$V_{40i(-1)}^c/(\gamma+\delta_i)$ .16662 14.77		.8531 (111)
10 Other manufacturing 144.44 1.10	$(K_{i(-1)}^c/L_{i(-1)}^c)(\Delta L_i^c+\Delta L_{i(-1)}^c)$ .21253 2.26	$(1-\delta_i)(K_{i(-1)}^c-\nabla K_i^c)$ .27116 15.54		.8379 (111)

Notes: Each cell in columns 2 to 4 above carries the kind of variable, parameter value, and its t-value from top to bottom. Likewise the first column correponds to the intercepts while R-squares and the degrees of freedom are given in the last one.
V_{40}, γ and δ denote the operating surplus, the official discount and depreciation rates, respectively.

some sectors corresponds to possible delays in constructions.[†16] As we observe from the table, the regression results are generally good with the R-squares (adjusted for the degrees of freedom) ranging from 0.74 to 0.87, except for Sector 08 (Metal products).

While the manufacturing assets are obtained through the distributive models, the zonal housing constructions are calculated directly from the land acquired. This stems from the fact that the regional frame model only determines the housing investments, but not the housing units to be built in the Region. Although we deal with the housing types in six categories, we have prepared only two formulas, on the ground of their building types, in order to maintain their statistical significance.

(Single-family units; h = H1,H2,H3)

$$\Delta H_h^c = \underset{(6.58)}{3.3368}(\Delta L_h^c)^{\underset{(42.54)}{0.9641}}(VL_{-1}^c)^{\underset{(18.28)}{0.3336}}, \quad \bar{R}^2=0.9091,\ df=189. \tag{6.14a}$$

(Multi-family units; h = H4,H5,H6)

$$\Delta H_h^c = \underset{(214.0)}{40.710}(\Delta L_h^c)^{\underset{(653.4)}{1.0021}}(VL_{-1}^c)^{\underset{(89.89)}{0.2717}}, \quad \bar{R}^2=0.9998,\ df=189. \tag{6.14b}$$

It must be noted that the above parameters are estimated log-linearly using the data aggregated into two categories, but the values for six categories will be predicted separately in actual simulations.

6.3. The Stock Accounting Submodel

With the land acquired ΔL_i^c, and associated stock increments in terms of manufacturing assets ΔK_i^c and housing units ΔH_h^c being determined through the previous subsection, we here calculate the existing amount of land, manufacturing assets and housing units, L_i^c, K_i^c and H_h^c.

$$L_i^c = L_{i(-1)}^c - \nabla L_i^c + \Delta L_i^c, \tag{6.15a}$$

†16. By the same reasoning as in Footnote 14 above, the parameters are primarily estimated with the data set comprising 38 zones excluding Saitama Pref. over 4 years. However, for those sectors where the land acquisition over the two-year period is employed, the number of effective years of observations will decrease to 3 years.

$$K_i^c = (1-\delta_i)(K_{i(-1)}^c - \nabla K_i^c) + \Delta K_i^c, \tag{6.15b}$$

$$H_i^c = H_{i(-1)}^c - \nabla H_h^c + \Delta H_{i(-1)}^c, \tag{6.15c}$$

where the present values are calculated from those in the previous period by subtracting demolitions and adding increments. Incidentally, assets corresponding to the capital depreciations must also be subtracted from the surviving assets for manufacturing sectors.

The major role of this submodel is to translate the existing amounts of land and manufacturing assets into the numbers of employees E_i^c in the present period. However, the employments in the non-basic sectors, which are defined as the ones not consuming urban land, are excluded here from our considerations as they are the subject in the auxiliary location sub-model. In this case, the models also become distributive by nature since we can expect the control totals to the regional frame model, in the form of regional employments.

In manufacturing sectors, the distributions are made in accordance with the following formula.

$$\hat{E}_i^c = \beta_0 (K_i^c)^{\beta_1} \left(\frac{V_{41i(-1)}^c}{K_{i(-1)}^c}\right)^{\beta_2} \left(\frac{V_{39i(-1)}^c}{E_{i(-1)}^c}\right)^{-\beta_3}, \tag{6.16}$$

where V_{41i} and V_{39i} represent the depreciations of fixed capital and compensations to employees in the sector, respectively. This expression can be obtained through a similar argument as we have derived the expression for the regional employments (5.22), i.e., both are derived from the first-order condition to the producer's problem under a production function of the Cobb-Douglas type. Besides the difference that eq.(5.22) has a log-linear form, eq.(5.16) explicitly includes the capital stock K, which is available to the manufacturing sectors, and keeps the capital rent r in the form of $V_{41i(-1)}/K_{i(-1)}$, which represents the cost paid for depreciating the existing assets in the previous period. The parameters associated with eq.(6.16) are estimated log-linearly, and summarized in Table 6.5.†17

On the other hand, the employments in non-manufacturing sectors are

Table 6.5. Estimated parameters for employments in manufacturing sectors.

	β_0	β_1	β_2	β_3	$\bar{R}^2$
03	4.120 10.85	.9432 69.70	.8654 18.65	.9057 30.12	.9602 (206)
04	5.447 9.76	.9607 46.10	.7410 10.19	.7599 12.83	.9139 (206)
05	3.740 15.14	.9529 88.58	.8347 25.66	.8809 28.06	.9741 (206)
06	5.919 14.87	.9381 73.98	.8265 14.28	.6670 14.85	.9710 (206)
07	1.668 5.12	.9171 74.30	.8204 22.07	.8716 38.74	.9641 (206)
08	3.274 9.51	.9388 62.45	.9387 18.77	.8199 16.70	.9505 (206)
09	3.260 14.26	.9846 123.0	.8404 26.64	.9688 31.43	.9882 (206)
10	3.322 15.99	.9748 107.6	.9030 35.55	.9951 27.44	.9825 (206)

Note: t-values are shown below each parameter, and $\bar{R}^2$ is the determination coefficient adjusted for the degree of freedom, which is shown within parentheses.

distributed in accordance with the values of the following formula.

$$\hat{E}_i^c = \beta_0 + \beta_1 E_{i(-1)}^c \left(1 - \frac{\nabla L_i^c}{L_{i(-1)}^c}\right) + \beta_2 VL_{-1}^c \Delta L_i^c, \tag{6.17}$$

where the term associating β_1 corresponds to the past employment records to be expected with the employments removed by demolition being subtracted proportionally. While the removal of employments is considered at the average rate between the existing employees and land occupied in the previous period, the employments attached to the newly acquired land is assumed to be affected by its property values, evaluated at the posterior land prices VL_{-1}^c. These arguments reflect the facts, on one hand that it is impossible to follow the histories of each lot in macro simulations, and on

†17. Here again, the C-level zones in Saitama Pref. are excluded from the data. In return, Saitama as well as the northern three prefectures are regarded as to constitute the P-level zones by themselves, and this makes the effective data for the calculations of Table 6.5 include 210 observations comprising 42 zones over 5 years.

the other that the high floor-to-area ratios are likely with the increase in land prices, resulting in high employment densities. Meanwhile, a formula alternative to eq.(6.17) is used in conjunction with Sectors 13, 17 and 33 to improve its explanatory power.

$$\hat{E}^c_i = \{\beta_0 + \beta_1 E^c_{i(-1)}(1 - \frac{\nabla L^c_i}{L^c_{i(-1)}}) + \beta_2 \Delta L^c_i\}(VL^c_{-1})^{\beta_3}, \qquad (6.18)$$

whose parameters are estimated through non-linear regressions.

Table 6.6 summarizes the parameters associated with employment distributions in non-manufacturing sectors, from which we observe the extremely high values of R-squares, which are adjusted for the degrees of freedom whenever linear regressions apply.†18 This could be understood from the fact that the expressions (6.17) and (6.18) both reflect the numbers of

Table 6.6. Estimated parameters for employments in non-manufacturing sectors.

	β_0	β_1	β_2	β_3	$\bar{R}^2$
11	-5.206 6.81	1.006 882.1	.1748 52.53		.9998 (188)
13	-6.682 0.27	.6857 16.80	21.77 19.71	.0547 7.94	.9967 (188)
14	225.4 9.98	.9996 1901.	.2361 36.94		1.000 (188)
16	2.332 1.87	.9998 3966.	.0392 139.7		1.000 (185)
17	-25.34 2.15	.7804 47.50	21.32 38.95	.0366 15.34	.9998 (184)
18	81.63 2.15	1.004 909.4	.1438 69.36		1.000 (185)
19	-1.771 5.71	1.004 2196.	.1485 70.04		1.000 (188)
21	28.87 4.20	1.000 1220.	.0289 46.84		.9999 (189)
22	69.72 8.73	.9968 1196.	.0399 57.82		.9999 (189)
23	15.07 6.62	.9999 2500.	.2397 32.79		1.000 (185)
24	187.8 10.54	.9983 1222.	.1834 17.20		.9999 (188)
25	487.4 7.42	1.011 156.8	.1419 8.13		.9996 (188)
26	33.96 10.69	.9986 1697.	.2105 33.13		1.000 (188)
28	10.36 3.16	.9989 2606.	.0413 138.7		1.000 (188)
29	-.3231 0.50	.9999 9749.	.0441 129.5		1.000 (188)
30	319.4 5.52	.9997 701.6	.3306 152.5		.9997 (188)
31	387.7 9.48	.9940 748.5	.3251 17.98		.9998 (185)
33	-79.35 3.50	.9096 117.2	22.58 30.92	.0150 14.62	.9999 (187)
34	.5566 1.49	.9998 9349.	.0424 157.8		1.000 (185)
35	-7.434 6.54	1.005 1278.	.1588 95.95		.9999 (188)

Notes: t-values are shown below each parameter, and $\bar{R}^2$'s are the determination coefficients adjusted for the degrees of freedom, which are given within parentheses.
For sectors 13, 17 and 33, the SSR/SST values and the asymptotic t-values replace them.

†18. Since both eqs.(6.17) and (6.18) contain lagged variables, Table 6.6 is based on up to 192 observations comprising 48 zones in the Southern Kanto Region over 4 years, out of which those lacked in land area data are dropped. In the sectors to which eq.(6.18) applies, the SSR/SST values are shown in place of R-squares due to its nonlinearlity.

employees in the previous period as one of the explanatory variables, which are so definitive in determining those in the succeeding period, particularly when the simulation cycle is merely a year. Nevertheless, it is noteworthy that this would not ruin the significance of other variables.

6.4. The Auxiliary Location Submodel

The variables to be distributed through this submodel can be classified into two categories, viz. (a) the capital formations other than manufacturing and (b) the employments in the non-basic sectors, each of which will be discussed in the succeeding subsections.

6.4.1. Non-manufacturing capital formations

i) Non-manufacturing, non-housing capital formation ΔK_N: With the government capital formations considered separately, this category corresponds to the investments made by all the industrial activities except for manufacturing and government services (Sectors 03 through 10, 17, 29 and 34). Naturally, it is impossible to disregard the public sector as a major supplier of community services, but it must be noted that most of such services can also be supplied by the private sector. Accordingly, we here consider that the investments associated with community services constitute some parts of ΔK_N, whose distributive measure is given by

$$\Delta\hat{K}^c_N = \underset{(8.45)}{33415} + \underset{(1.73)}{0.1917}VL^c_{-1}\Delta L^c_N + \underset{(16.0)}{0.4800}V^c_{40N(-1)}, \quad \bar{R}^2 = 0.9340, \ df=189, \qquad (6.19)$$

where the subscript N identifies that the variable is summed up over the 24 sectors relevant to this category. Eq.(6.19) implies that the amount to be invested would increase wherever the property values of acquired land is high or the operational surpluses are relatively abundant.

ii) Housing investments IR, IGR: We have two formulas depending on whether funding is provided by the private or public sectors. The distributive measure for the private investment reflects the numbers of newly constructed housing units along with that of existing units.

$$\hat{IR}^c = 4286 + 7.072\Delta H^c_S + 5.886\Delta H^c_M + 0.0377H^c_{-1}, \quad \bar{R}^2 = 0.9715, \qquad (6.20)$$
$$(4.54) \quad (34.2) \quad (19.4) \quad (3.62) \quad df=251,$$

where the subscripts S and M indicate the single-unit and multi-unit houses, respectively, and the last term is expected to represent the maintenance costs.

While the categorization of housing construction by building types brings a better result concerning the private investment, that by housing tenures is employed for the investment by the public sector. This stems from the fact that most of the public housing is provided as the multi-unit houses. Namely,

$$\hat{IGR}^c = -14.99 + 0.3262\Delta H^c_O + 0.5404\Delta H^c_R + 2.836\Delta H^c_I, \quad \bar{R}^2 = 0.6916, \qquad (6.21)$$
$$(0.07) \quad (8.66) \quad (8.88) \quad (5.39) \quad df=302,$$

where the subscripts O, R and I indicate the owned, rented and issued units, respectively.

As the above regressions do not involve variables concerning the land use, we might use the full 51 zones, including the northern three prefectures, as the effective observations. These observations have been pooled over the maximum possible years given the lagged variables, and this practice will be maintained whenever it is possible hereafter.

iii) Government capital formation except housing IG: The distributive measure for this item is given by the following formula.

$$\hat{IG}^c = 17391 + 0.6945PVA^c_{-1} + 0.0692N^c_{-1} + 155458D_{1-3}, \quad R^2 = 0.8466, \qquad (6.22)$$
$$(4.49) \quad (21.6) \quad (12.6) \quad (13.0) \quad df=251,$$

where D_{1-3} is the dummy variable applicable to the northern three prefectures, and PVA_{-1} is the potential variable concerning the zonal value added in the previous period defined by

$$PVA^c_{-1} = \Sigma_{c'} VA^{c'}_{-1} \exp(-0.5262TF^{cc'}),$$

whose parameters are determined simultaneously with the linear parameters through an iterative procedure.†19

6.4.2. Non-basic employments

As mentioned in Section 6.2, what we need to determine here are the zonal employments in industrial activities which are not classified as the locating ones. Namely the distributive measures for employments in the non-urban activities as well as those in construction sectors are to be formulated. The former category includes Sectors 01 and 02, each of which is formulated with a potential variable.

(01 Agriculture, forestry and fisheries)

$$\hat{E}^c_1 = 1.0241(E^c_{1(-1)})^{0.9986}\left(\frac{PEU^c}{PEU^c_{-1}}\right)^{-2.208}, \quad R^2 = 0.9995, \qquad (6.23)$$
$$(1.43) \quad (663) \quad (1.99) \quad df=252,$$

(02 Mining)

$$\hat{E}^c_2 = 1.0857(E^c_{2(-1)})^{0.9811}\left(\frac{PIRR^c}{PIRR^c_{-1}}\right)^{0.6372}, \quad R^2 = 0.9753, \qquad (6.24)$$
$$(2.01) \quad (99.7) \quad (1.90) \quad df=252,$$

where the parameters are estimated log-linearly, and PEU and PIRR are the potential variables reflecting the zonal accessibilities to urban employees and the housing investments, given respectively by the following formulas.

$$PEU^c = \Sigma_{c'} EU^{c'} \exp(-0.00941TM^{cc'}),$$
$$PIRR^c = \Sigma_{c'} (IR^{c'} + IGR^{c'}) \exp(-0.0219TF^{cc'}).$$

The fact that PEU is negatively correlated with E_1 can easily be understood as the conversion of agricultural land to urban usages would be accelerated by the existence of urban employees. And the reason why the housing investments explain E_2 is that products of mining in our study area mostly come from quarrying as construction materials, and the industrial investments are not necessarily connected with constructions.

Next we proceed to the formulations of the distributive measures associated with employments in construction sectors.

†19. Similarly as in the case of estimating the distance decay parameters in the bid price functions, an unconstrained nonlinear problem to minimize the sum of squared errors from the log-linear regression is solved to determine the parameter included in the potential variable. This argument also applies to the potential variables which appear in the next subsection.

(12 Non-residential building)

$$\hat{E}^c_{12} = \underset{(0.07)}{-11.43} + \underset{(23.3)}{0.9125E^c_{12(-1)}} + \underset{(2.93)}{0.00224(IF^c+IG^c)}, \quad \bar{R}^2 = 0.9448, \ df=207, \qquad (6.25)$$

where $IF = \Sigma^{10}_{i=3}\Delta K_i + \Delta K_N$ is the total non-housing investment by the private sector, and IG is its public counterpart, and the degree of freedom indicates that Saitama Pref. as a whole is regarded as an observation. This formula considers the financial sources of non-residential building constructions, and the similar argument applies to the rest of the construction sectors.

(20 Residential building)

$$\hat{E}^c_{20} = \underset{(0.84)}{-175.2} + \underset{(35.9)}{0.8444E^c_{20(-1)}} + \underset{(3.44)}{0.0156IR^c} + \underset{(3.62)}{0.1961IGR^c}, \quad \bar{R}^2 = 0.9608, \ df=251, \qquad (6.26)$$

where IR and IGR are combined to represent the gross budget to finance residential constructions. Meanwhile, it is statistically impossible to classify the employees engaged in public works into the three jurisdictional levels which finance the respective projects. Accordingly, we here consider these employees as being associated with a combined sector of public works as a convention.

(C Public works combined)

$$\hat{E}^c_C = \underset{(0.58)}{-148.7} + \underset{(21.6)}{0.8109E^c_{C(-1)}} + \underset{(1.87)}{0.00442IF^c} + \underset{(3.50)}{0.0120IG^c}, \quad \bar{R}^2 = 0.9567, \ df=206, \qquad (6.27)$$

where E_C denotes the number of combined employees in Sectors 15, 27 and 32.

6.5. The Commuting Distribution Submodel

6.5.1. Basic concepts of residential location

With the numbers of employees in all the sectors being determined through the preceding discussions, we now allocate them to the housing units calculated in Section 6.3. Recalling that the major focus of this study does lie upon developing a comprehensive metropolitan model, rather than a detailed residential location model, the calculation of commuting OD distributions by means of a constrained gravity model suffices what we expect from this submodel. This can be explained as follows.

i) In the present model, stock allocation is said to be dominating in the sense that the land use configurations are first determined through the locational competition based on the bid prices. It is a common practice in the dynamic residential location models that the totally myopic behavior is assumed for the households as the tenants to the housing units while the perfect foresight about the future renter-time sequences is assumed for the developers who provide these units.[13),17)] This is partly because the costs born by households due to moving is much less than those associated with redevelopment of the site. In fact, if a developer is rational enough to build the housing stocks based on the accurate knowledge about household's behavior, it would be possible to regard the household's behavior as being subordinate to the developer's one. Further, if the model is aimed at describing the physical land use in the metropolitan area, the description about the histories of households in terms of changes in dwellings is not of our primary interest for the purpose.

ii) When we deal with the locations of housing stocks and their tenants independently, it is possible to analyze the generation of vacant houses as a result of disequilibrium in the housing market. Incidentally, the relevant data are compiled mainly from the *Population Census* which is based on surveys conducted concerning households.[5)] This implies that the vacancy predicted by the model based on such data must be understood as a kind of model errors.[†20]

Finally it must be noted that we do not explicitly consider the types

†20. Although the housing stocks are explicitly considered in seven out of nine ISGLUTI models[18)], only AMERSFOORT, DORTMUND, LILT and MEP consider the allocations of housing stocks and population through separate mechanisms. To explicitly consider the housing market, the dependable data on housing stocks are indispensable, and the *Housing Survey* or the *Statistical Survey on Building Construction* are expected to provide such information. However, the fact that the former survey is conducted concerning the existing households and that the latter survey seems not paying much attention on the usages of the buildings after construction, they both fail to provide independent data concerning housing stocks.

of households in our study, and this is equivalent to assume a one-to-one correspondence between households and housing types. That is, households who reside in the single-unit owned houses are considered to constitute a class by themselves.

6.5.2. Commuting OD distributions

Suppose the number of employees who work in zone r and reside in houses of type h in zone s is denoted by E_h^{rs}, and its marginal distributions are denoted by $E_h^{r\cdot} = \Sigma_s E_h^{rs}$ and $E_h^{\cdot s} = \Sigma_r E_h^{rs}$, respectively. Then the doubly constrained gravity model suggests that the description for E_h^{rs} is given by the following formula.[19)]

$$E_h^{rs} = C_h^r D_h^s E_h^{r\cdot} E_h^{\cdot s} \exp(-\beta_h TM^{rs}), \tag{6.28}$$

where C_h^r and D_h^s are the adjustment constants associated with the job and residential sites, respectively. The distance decay parameters β_h relevant to each housing type are calculated for the two census years, 1975 and 80, and summarized in Table 6.7. With β_h being interpolated linearly for years inbetween, the probability to choose each housing type is calculated at the place of work in accordance with the accessibility to houses of each type.

$$p_h^r = \frac{\alpha_h[\Sigma_s H_h^s \exp(-\beta_h TM^{rs})]^{\gamma_h}}{\Sigma_{h'} \alpha_{h'}[\Sigma_s H_{h'}^s \exp(-\beta_{h'} TM^{rs})]^{\gamma_{h'}}} \tag{6.29}$$

The parameters $\{\alpha_h\}$ and $\{\gamma_h\}$ are estimated through a nonlinear simultaneous regression (OLS), and summarized in Table 6.8.

In practice, the housing demands in terms of employees at each job

Table 6.7. Distance decay parameters by housing types.

	Single-unit houses			Multi-unit houses		
	Owned	Rented	Issued	Owned	Rented	Issued
1975	.06342 (2493)	.06422 (2222)	.06614 (1650)	.06579 (1686)	.06368 (2136)	.06529 (1805)
1980	.06112 (2556)	.06185 (2314)	.06365 (1718)	.06321 (1835)	.06162 (2216)	.06305 (1859)

Note: The numbers in parentheses indicate the numbers of non-zero observations out of 2601(=51x51) elements of the commuting matrix.

Table 6.8. Paremeters for the housing type selection probabilities.

	α_h	γ_h	R^2		α_h	γ_h	R^2
Single-unit owned	1. fixed	1.2217 (29.0)	.8920	Multi-unit owned	0.1221 (2.50)	1.4355 (37.8)	.8630
Single-unit rented	1.0582 (5.89)	1.2438 (33.6)	.8782	Multi-unit rented	0.0628 (2.60)	1.4281 (44.5)	.8998
single-unit issued	2.0352 (3.64)	1.2373 (25.9)	.6912	Multi-unit issued	0.4827 (2.84)	1.3229 (32.4)	.7936

Note: Asymptotic t-values are shown within parentheses, where the degree of freedom for each housing type is fixed at 100.

site are first divided into housing types they reside in using $E_h^{r\cdot} \equiv p_h^r E^r$. For simplicity, we introduce the following assumption.

Assumption 6.1. The number of employees in each household does not vary across zones given a housing type.

Then the division of demands to the housing types at the residential site is definitionally given by

$$E_h^{\cdot s} \equiv (H_h^s / \Sigma_s H_h^s) \Sigma_r E_h^{r\cdot}. \tag{6.30}$$

Incorporating the demands at both job and residential sites obtained above into eq.(6.28), we can readily compute the commuting OD distributions.

Once the numbers of employees are obtained at the places of residences, the population accompanied with these employees can easily be calculated under the above assumption. Namely, the distributive measure for the zonal population is given by

$$\hat{N}^s = \underset{(6.06)}{1.307}(\underset{(6.10)}{3.340}E_O^{\cdot s} + \underset{(5.89)}{4.265}E_R^{\cdot s} + \underset{(\infty)}{5.122}E_I^{\cdot s})(VL_{-1}^s)^{\underset{(9.78)}{-0.1243}}, \quad SSR/SST= 0.9982, \quad df=92, \tag{6.31}$$

where the employees are categorized by the tenures of houses they live in with the subscripts O, R and I denoting the number of employees residing in the owned, rented and issued houses, respectively. As the nonlinear regression is required to estimate the parameters, the asymptotic t-values are shown within parentheses. The fact that the land price VL is negatively correlated with the population can be explained by the fact that the more family nuclei can be found where high land prices are observed, and it is more likely to bring high percentages of employment.

6.6. The Demolition Submodel

6.6.1. The posterior land price function

The land prices are obtained as a consequence of locational competition in the period. Hence, we calculate the posterior land prices at the end of each simulation cycle as mentioned earlier, and forward them to the succeeding period as one of the major locational information. Yamada *et al.* have found from the cross-sectional data in 1968 that the population densities could well explain the average land prices at the zones comparable to our C-level zones.[20] While their results were based on the loan records of the *Housing Loan Corporation*, the most extensive sets of land price data are available in *Public Notification of Land Prices*. As the density-type land price function has also been found effective with these data at least cross-sectional applications are concerned,[21] we here combine the average annual price increase rate with the density-type function to calculate the posterior land prices.[†21]

$$\underset{}{VL^c} = \underset{(236.1)}{1.0828}^{t-75}\{\underset{(8.83)}{231.6} + \underset{(14.6)}{4.226}(N^c/LF^c) + \underset{(61.5)}{12.66}(EU^c/LF^c)\},\quad SSR/SST= 0.9841,\ df=284, \tag{6.32}$$

where 8.28 % is the annual price increase rate as compared with the 1975 prices during our study period. The densities in eq.(6.32) are based on the inhabitable land, and the employments in urban activities are used to express the price segments accrued from non-residential usages.

6.6.2. Demolition probabilities

In the case of location probabilities, we employed the multinomial logit model to describe competitions among locating activities. Despite the fact that demolitions are also resulted from such competitions, the

†21. Since the notifications are made as of January 1 each year, these data are used to calculate the posterior land prices in the previous year. Meanwhile, the density-type function has also been proved effective to predict land prices in a disaggregative context, viz. at each notification point. This can be done by regarding the portion of the land price explained by zonal densities as the base price in the zone, which is then adjusted by the hedonic measures at each point.[22)]

causalities due to locations of other activities seem relatively weak in the sense that the internal causes and the general circumstances are the key factors to determine demolitions. Hence, we formulate the demolition probabilities through binary logit models independently of other activities. Meanwhile, it is possible to define the probabilities either in terms of existing amount of land in the previous period, $\nabla L_i^c(t)/L_i^c(t-1)$, or of the location entities, e.g. $\nabla K_i^c(t)/K_i^c(t-1)$ for manufacturing assets, where the latter approach is employed by the following reasoning. Namely, i) the land area data are less reliable as compared with those concerning location entities in the sense that the former are estimated through complicated data processing as discussed in Section 6.1. In addition, ii) we are obliged to regard the land areas released by demolitions as being proportional to the associating entities since it is impossible to follow the histories of constructions on the basis of aggregate zones.

As the changes in employments are available in the form of net increases, we consider that the demolitions are present only when the net decreases are observed for the non-manufacturing sectors whose entities are the employees. That is, the demolition probability $\nu_i^c(t)$ is given by

$$\nu_i^c(t) = -\min(E_i^c(t)-E_i^c(t-1),0)/E_i^c(t-1). \tag{6.33}$$

It must be noted that the decrease in employments does not necessarily entail the release of land while the latter necessarily results in the former. And this is one of the reasons why the total employments are calculated in the stock accounting submodel in each simulation cycle.

In addition, the actual simulations require us to calculate the land areas released from removal of entities. In this regard, we identify the demolition probabilities in terms of land area with those of location entities despite their definition as above. Accordingly, when we denote the demolition probability based on entities by ν_i^c, the land attached to that demolition $\nabla L_i^c(t)$ is simply defined as

$$\nabla L_i^c(t) = \nu_i^c(t)L_i^c(t-1). \tag{6.34}$$

Similarly as in the case of location probabilities, the demolition probability is then defined by a binary logit function based on the demolition scores Ω^c_i in place of the bid prices.

$$\gamma_i^c = 1/(1 + \exp(-\Omega_i^c)), \tag{6.35}$$

where Ω_i^c is given by a linear function of the demolition factors X_{ik}^c,

$$\Omega_i^c = \gamma_{io} + \Sigma_k \gamma_{ik} X_{ik}^c. \tag{6.36}$$

6.6.3. The demolition factors

We consider the following twelve factors as being relevant to demolitions, where the superscripts c to indicate zones are omitted.

(a) The indices related to land areas and land prices: The vacant land ratio, LA_{-1}/LF, the relative difference between the zonal land price and the regional average VL^R, $(VL-VL^R)_{-1}/VL^R_{-1}$, the relative difference between the land area which the concerned activity is expected to occupy in terms of the stock probability ρ_i and the actual one, $(\rho_i LF-L_i)_{-1}/L_{i(-1)}$, and the relative productivity per unit land of the activity as compared with the average one, $(VA_i/L_i)_{-1}/(VA/L)_{-1}$.

(b) Increase rates in employments and population: The increase rate in non-manufacturing basic employments, $\Delta EB_{-1}/EB_{-2}$, and the one in population, $\Delta N_{-1}/N_{-2}$.

(c) Increase rates in productions and values added: The increase rate in production, $\Delta X_{i(-1)}/X_{i(-2)}$, the one in value added, $\Delta VA_{i(-1)}/VA_{i(-2)}$, and its regional counterpart, $\Delta VA^R_{i(-1)}/VA^R_{i(-2)}$, to represent whether the activity is in the growing or declining phase on the average.

(d) Increase or decrease rates in location entities: The demolition ratio in terms of entities in the previous period, e.g. $(\nabla K_i/K_i)_{-1}$, the proportion of newly added amount of entities to the existing one, e.g. $(\Delta K_i/K_i)_{-1}$, and the ratio between the net increase and the stock, e.g. $(\Delta K_i-\nabla K_i)_{-1}/K_{i(-1)}$.

In the above, the basic activities refer to those subject to the location and demolition analyses, viz. the locating activities, as mentioned in Section 6.2. Thus when we denote the set of manufacturing activities by M, the non-manufacturing basic employment is defined as $EB^c \equiv \Sigma_{i \in B \setminus M} E_i^c$ using the set of locating activities B other than residential ones. Similarly, the denominator of the "relative productivity" is calculated for those activities, viz. $VA^c/L^c = \Sigma_{i \in B} VA_i^c / \Sigma_{i \in B} L_i^c$. Meanwhile, the factors in (d) are the inertial terms to represent the local trends of the activities in the forms of either net increase or the pair comprising gross increase and decrease. Note again that when the employments are the location entity, ΔE_i^c and ∇E_i^c of the latter form must be replaced by $\max(E_i^c(t) - E^c_{i(-1)}, 0)$ and $-\min(E_i^c(t)-E^c_{i(-1)}, 0)$, respectively, while the net increase is denoted by $DE_i^c \equiv \Delta E_i^c - \nabla E_i^c$.

6.6.4. Estimated demolition scores

To determine the parameters in eq.(6.36), it is necessary to regress eq.(6.35) nonlinearly by incorporating the former. While the numbers of observations available for the purpose are ranging from 38 to 47 zones over the four year period, it seems almost impossible to obtain stable estimators from them on the activity basis due to the discrete nature of demolitions. And this is the reason why we estimate the parameters for seven categories shown in column DM of Table 6.1. Nevertheless, it has been proved necessary to estimate parameters by taking moving averages of the variables in both sides of eq.(6.35) for category M, the manufacturing sectors, as the estimation based on the raw data carries unstable results. In such a case, the years of effective observations are to be reduced to three years. It must be noted, however, the demolition probabilities are calculated for individual activities using the parameters of the category to which they belong. The functional forms of the demolition scores along with their parameters are summarized in Table 6.9. As seen from the table, the explanatory variables are selected from those representing relative

Table 6.9. The estimated functions of demolition scores and probabilities.

Manufacturing $\nu_i=\nabla K_i/K_{i(-1)}$ SSR/SST=0.4695 df=107

$$\Omega_i=-3.900+0.0530\left(\frac{VL-VL^R}{VL^R}\right)_{-1}-5.505\frac{\Delta EB_{-1}}{EB_{-2}}+10.96\frac{\Delta N_{-1}}{N_{-2}}-3.456\frac{\Delta VA_{i(-1)}}{VA_{i(-2)}}+0.2246\left(\frac{VA_i/L_i}{VA/L}\right)_{-1}+10.19\left(\frac{\nabla K_i}{K_i}\right)_{-1}$$

(39.3) (2.93) (2.64) (3.23) (4.03) (3.50) (6.14)

Transportation $\nu_i=\nabla E_i/E_{i(-1)}$ SSR/SST=0.6329 df=183

$$\Omega_i=-3.852+0.3874\frac{LA_{-1}}{LF}-5.503\frac{\Delta VA^R_{i(-1)}}{VA^R_{i(-2)}}+24.08\left(\frac{\nabla E_i}{E_i}\right)_{-1}-6.315\left(\frac{\Delta E_i}{E_i}\right)_{-1}$$

(34.3) (3.06) (6.59) (12.4) (4.06)

Commercial $\nu_i=\nabla E_i/E_{i(-1)}$ SSR/SST=0.5643 df=183

$$\Omega_i=-4.115-0.9242\frac{LA_{-1}}{LF}+22.26\frac{\Delta EB_{-1}}{EB_{-2}}+5.133\frac{\Delta VA_{i(-1)}}{VA_{i(-2)}}-46.37\left(\frac{DE_i}{E_i}\right)_{-1}$$

(27.5) (2.68) (2.42) (2.97) (6.80)

Public $\nu_i=\nabla E_i/E_{i(-1)}$ SSR/SST=0.7766 df=181

$$\Omega_i=-5.241+0.4496\frac{LA_{-1}}{LF}+0.0430\left(\frac{VL-VL^R}{VL^R}\right)_{-1}-3.947\frac{\Delta EB_{-1}}{EB_{-2}}-6.880\frac{\Delta N_{-1}}{N_{-2}}-5.510\frac{\Delta VA_{i(-1)}}{VA_{i(-2)}}+52.52\left(\frac{\nabla E_i}{E_i}\right)_{-1}$$

(42.2) (2.63) (2.95) (2.82) (2.66) (6.40) (17.8)

Utility $\nu_i=\nabla E_i/E_{i(-1)}$ SSR/SST=0.9409 df=181

$$\Omega_i=-5.025+4.848\frac{\Delta EB_{-1}}{EB_{-2}}-0.8475\left(\frac{\rho_i LF-L_i}{L_i}\right)_{-1}-1.094\frac{\Delta VA_{i(-1)}}{VA_{i(-2)}}+0.1855\left(\frac{VA_i/L_i}{VA/L}\right)_{-1}+1.930\frac{\Delta VA^R_{i(-1)}}{VA^R_{i(-2)}}-25.34\left(\frac{DE_i}{E_i}\right)_{-1}$$

(42.9)(2.53) (9.77) (3.40) (12.3) (4.24) (27.2)

Single-family Houses $\nu_h=\nabla H_h/H_{h(-1)}$ SSR/SST=0.8293 df=183

$$\Omega_h=-4.407+0.3549\frac{LA_{-1}}{LF}+0.0853\left(\frac{\rho_h LF-L_h}{L_h}\right)_{-1}+32.20\left(\frac{\nabla H_h}{H_h}\right)_{-1}-7.482\left(\frac{\Delta H_h}{H_h}\right)_{-1}$$

(65.5) (6.61) (1.97) (27.8) (5.19)

Multi-family Houses $\nu_h=\nabla H_h/H_{h(-1)}$ SSR/SST=0.6836 df=182

$$\Omega_h=-3.882+0.8446\frac{LA_{-1}}{LF}+0.0595\left(\frac{VL-VL^R}{VL^R}\right)_{-1}-7.128\frac{\Delta EB_{-1}}{EB_{-2}}+6.956\left(\frac{\nabla H_h}{H_h}\right)_{-1}+2.206\left(\frac{\Delta H_h}{H_h}\right)_{-1}$$

(33.3) (4.44) (3.93) (5.45) (10.6) (2.94)

magnitudes to facilitate individualized applications.

The factors to be included in respective scores are selected in a systematic way. We first formulate a score reflecting all the possible variables, except for alternative ones, and successively drop the variables which are associated with the smallest absolute values of the asymptotic t statistics, until all the variables in the function become statistically significant. Then the function which results in the highest SSR/SST value is selected. In particular, we do not pay specific attention to the signs

associated with respective variables. As a matter of course, the factors accompanied by positive parameters will promote the demolitions, while those with negative ones will suppress them, but interpretations of variables are generally possible in either case.

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CHAPTER 7

TEST SIMULATIONS

Having all the formulations in the metropolitan simulation model been completed, it is now possible to execute test simulations corresponding to the final tests in econometric models. While our model comprises three major blocks; the regional frame, activity, and location models, the latter two blocks are of major concern in this chapter. In practice, the tests are made in two phases to identify the performance of each model block; the flow simulations where the stock variables are given exogenously, and the total simulations to clarify the performance of the location model. The respective results are discussed after reviewing the simulation procedures.

7.1. Simulation Procedures

While the full relationships among model blocks and subordinate sub-models in our metropolitan model have been depicted in Figure 3.1, it might be too complicated to understand the actual execution procedures. In this connection, Figure 7.1 is prepared to clarify the order in which those submodels are linked, although we refrain from repeating their roles here. As we observe from the figure, the regional frame model, including the regional level I-O analysis, is executed at the beginning of each cycle to provide the control totals to the activity and location models, of which the latter follows immediately to determine the spatial distributions of stock variables. When the execution of the location model proceeds to the commuting OD distributions, we can return to the activity model where the 3LIO analysis is completed down to the C-level zones. It must be noted, however, the results reported in this chapter would still be partial in the sense that a part of the regional variables, such as the regional employments by sectors and the investment items, to be calculated in the regional frame model are given exogenously. This is partly because that block is

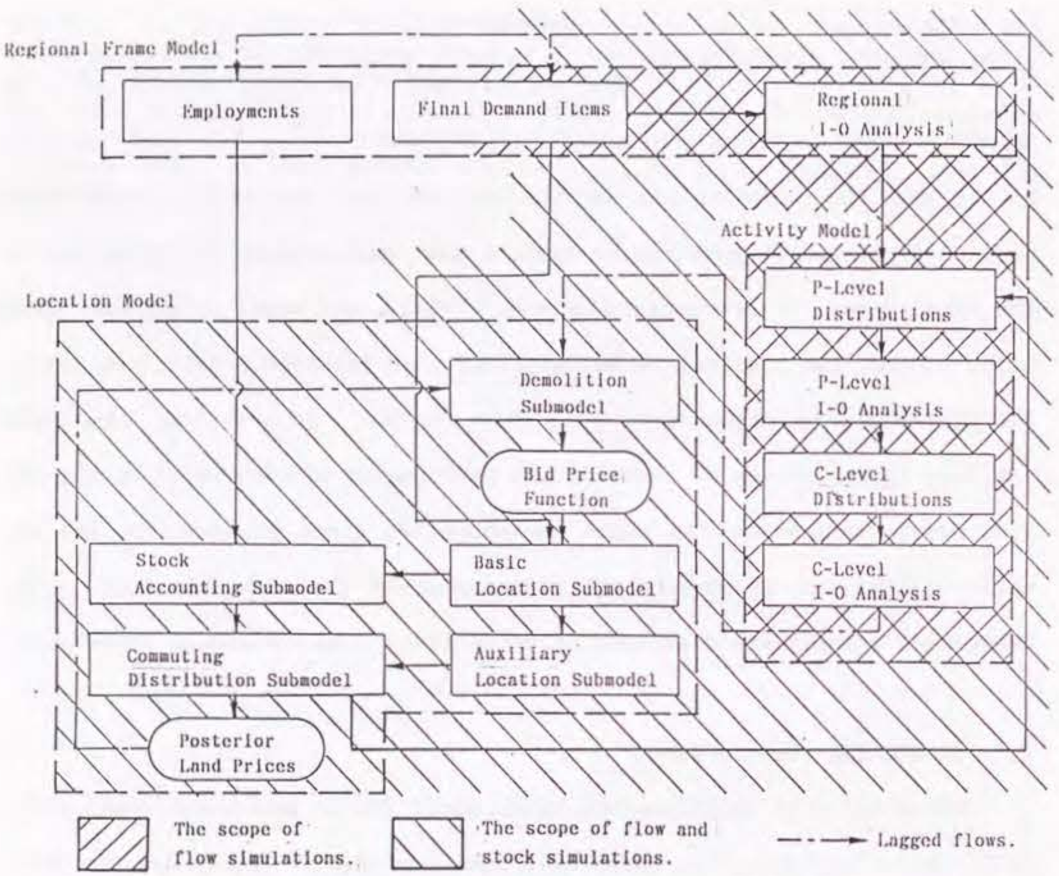

Figure 7.1. The simulation procedures of the model.

basically intended to make necessary adjustments among a variety of exogenous standard values while expecting outside models to provide them.

Two types of test simulations are conducted in the study. One is the flow simulations whose scope is limited to the 3LIO model as shown in the figure, where the spatial distributions of stock variables are given the observed values. The other is the total, or the flow and stock, simulations which are intended to test the overall performance of the activity and location models, as well as a part of the regional frame model, where the distributions of both flow and stock variables are determined endogenously. In any case, the tests conducted in the study might be called *quasi-final* in the sense that they encounter several operational limitations due to insufficient data availability along with a number of measures to avert drastic changes in model predictions.

The test simulations are carried out concerning the area and period over which the data for estimating model parameters are collected, viz. Tokyo Metropolis and the six surrounding prefectures during six years between 1975 and 80. Since the actual simulations require the data in 1975 as the initial values, the effective years for annual simulations reduce to five years starting in 1976 as far as the flow simulations, which generally require singly lagged variables, are concerned. However, the fact that the location model involves many doubly lagged variables necessarily reduce the number of effective years to four. In addition, the deficiency of land use data concerning the northern three prefectures inhibits us from endogenously predicting many stock related variables for these areas.

7.2. Flow Simulations[1)]

This section is devoted to the discussion of the flow simulations which covers the activity model and a part of the regional frame model related to the regional I-O analysis. However, the following limitations are observed in practice. First, i) due to data deficiency, the C-level computations are confined to the southern four prefectures, including Tokyo Metropolis, in 48 zones. ii) As the investment items, IR through IG, represent the stock increments, its spatial distributions are to be determined through the location model. Accordingly, those values as well as their regional values are given exogenously. And iii) the rest of the variables in the regional frame model, including the net exports and net increase in stocks, are determined endogenously without using the standard values from outside the model.

In other words, the models described in Sections 5.1 (except for 5.1.1), 5.3 and 5.4 are not activated in the present test. The second point is directly related to the nature of flow simulations that we cannot clarify the performance of relevant parts in the model unless the spatial allocations of variables to be determined in the location model, such as population and employments, are given exogenously. Regarding the third point, it would be reasonable to bypass the use of standard values to illuminate the model performance. The reason is that their incorporation would make the performance by itself less transparent in return for the consistency of the predictions with the existing macro statistics.

Although it is possible to extend the applicability of *Assumption 4.1* over the 11 prefectural region, it has been found inappropriate to use the input-output coefficients readily available from the regional input-output tables compiled by MITI. Hence, we follow the nonsurvey procedure discussed in Section 3.4 to adjust the input coefficients and the final demand converters compiled for the extended Region to meet the configuration of our study area. While the procedure significantly improves the projections of regional productions for both initial and terminal years, we employ ordinary RAS adjustments[2)] in response to the chronological changes of these coefficients for the years in-between as Figure 7.2 illustrates.[†1]

Our model inherits the assumption from the BIO model that the goods are classified in accordance with the area in which their supplies meet the demands. Although we allow the local goods to be traded beyond the Region

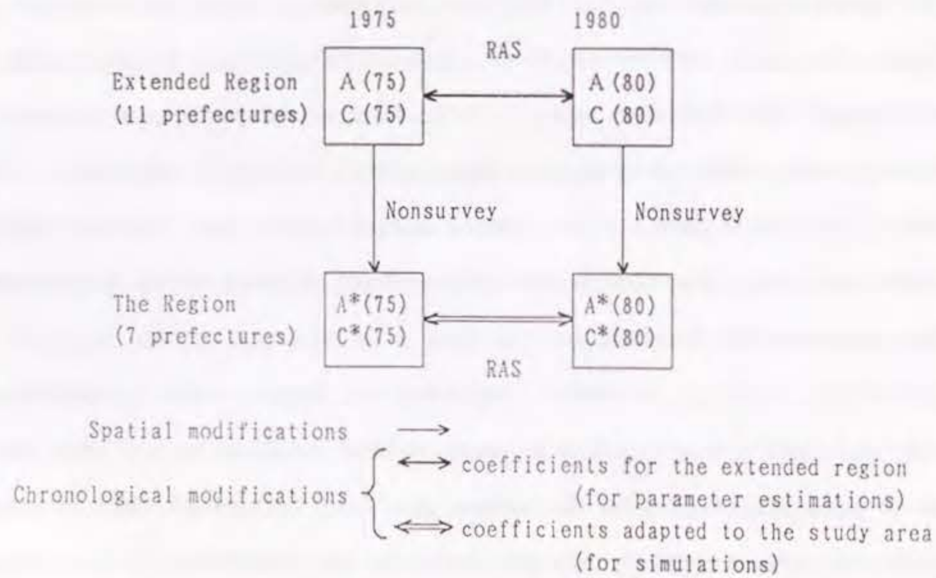

Figure 7.2. Relationship among sets of input coefficients and final demand converters.

in order to maintain their aggregative consistency, trades among localities within the Region are precluded. Hence, it will be meaningful to see whether our classification of goods is proper in terms of demand-supply imbalances. Table 7.1 summarizes the ratios of imbalances to the productions in the first and last years of our flow simulations, 1976 and 80.[†2] As the maxima and means at the regional level indicate, the R-level sectors generally demonstrate much active trading with the rest of the world. This appears to give an evidence that our sectorial classification is acceptable, even though an objective one by means of such imbalances is impossible by the reason mentioned earlier. For instance, the jurisdiction of the national government clearly reaches far beyond the Region, but it is among the eight sectors whose imbalances in monetary terms are zero by definition. In this connection, we allow intra-regional trades at a lower spatial level for such sectors, if they are classified as either R or P level activities.

Among the measures to evaluate the fitness of the model, root mean squared errors (RMSE), mean absolute percentage errors (MAPE), and

Table 7.1. The ratios of trade imbalance to production, $|FM_i^l|/X_i^l*100$ (%).

	1976				1980			
	Region		Spatial Means		Region		Spatial Means	
	Max.	Means	7 Prefs.	48 Zones	Max.	Means	7 Prefs.	48 Zones
R-level goods	62.42	6.06	71.06	253.6	57.14	4.79	67.31	689.6
P-level goods	2.29	1.07	→	48.92	1.61	0.61	→	50.31
C-level goods	1.94	0.84	→	→	0.79	0.35	→	→

Note: The columns for the Region show the maxima and means of imbalance ratios for sectors classified to each level. The columns for spatial means show the averages of cross-sectorial means over the spatial units designated.

†1. Since those coefficients will fluctuate depending on nonsurvey schemes employed, the model parameters are estimated with the ones observed for the extended Region. The RAS method is also applied separately to both input coefficients and converter matrices to obtain the estimates of coefficients to be used with the statistics for the years in-between.

†2. Table 7.1 is prepared with a similar intension as for Table 3.3. However, the imbalances shown in the former are based on the model predictions and evaluated at the lower spatial levels within the 7 prefectural region, while those in the latter are based on the original tables and for the 11 prefectural region as a whole.

correlation coefficient are commonly used. Suppose X_i^c and $\hat{X}_i^c$ are the observed and calculated values of productions of the i-th good in zone c, respectively. Then the former two statistics for the sector are defined as

$$\mathrm{RMSE} = \sqrt{\textstyle\sum_c (\hat{X}_i^c - X_i^c)^2 / n} \quad \text{and} \quad \mathrm{MAPE} = (100/n)\textstyle\sum_c |\hat{X}_i^c - X_i^c| / X_i^c,$$

where the summations are taken w.r.t. zones, and n=51 is the number of them, including the northern three prefectures. Tables 7.2 and 7.3 summarize those statistics for sectorial productions and consumption items, respectively.

Concerning productions, while the overall correlations experience

Table 7.2. Zone based error statistics for predicted values of productions.

SEC	1976			1980			SEC	1976			1980		
	RMSE	MAPE	CORR.	RMSE	MAPE	CORR.		RMSE	MAPE	CORR.	RMSE	MAPE	CORR.
01	14100	55.72	0.9887	14188	58.69	0.9889	19	2179	38.08	0.8811	2243	32.23	0.9250
02	31561	263.78	0.7633	17426	145.00	0.8579	20	8622	13.87	0.9930	30248	28.06	0.9678
03	36514	26.43	0.9471	34695	16.78	0.9618	21	43824	60.18	0.8600	32430	49.92	0.7446
04	14781	38.58	0.9840	11326	30.90	0.9850	22	25986	48.34	0.8724	17710	30.27	0.8567
05	20036	30.92	0.9951	13922	23.45	0.9959	23	18911	41.52	0.9343	24565	41.42	0.8868
06	22599	32.82	0.9927	29106	26.09	0.9983	24	156571	40.47	0.9365	184480	34.64	0.9145
07	64704	21.21	0.9795	149027	24.98	0.9715	25	84170	56.00	0.8912	129865	52.79	0.8419
08	23579	16.28	0.9941	85153	18.30	0.9508	26	20891	36.76	0.9369	28122	44.11	0.9005
09	65220	14.21	0.9829	90888	15.69	0.9838	27	25690	655.67	0.9091	38491	302.51	0.8560
10	35216	23.80	0.9899	42228	24.67	0.9866	28	8880	13.85	0.9767	7673	6.71	0.9705
11	11002	29.06	0.9747	23726	27.92	0.8860	29	8571	15.75	0.9844	17430	43.11	0.9860
12	17896	25.12	0.9755	65981	72.11	0.7800	30	48027	34.90	0.8712	57727	38.32	0.8354
13	13292	21.22	0.9942	10400	30.62	0.9973	31	63093	42.08	0.7563	65737	42.90	0.7122
14	215549	39.55	0.9720	316216	56.30	0.9411	32	8251	1327.2	0.8849	12350	469.31	0.8338
15	2493	756.83	0.9777	6781	272.71	0.9023	33	30350	35.10	0.8889	27970	32.38	0.8924
16	2493	10.12	0.9984	6542	5.62	0.9931	34	7044	28.54	0.8354	11535	51.69	0.8512
17	15712	105.64	0.9830	47110	52.62	0.9744	35	3455	39.36	0.8116	5554	36.81	0.7724
18	2665	1.36	1.0000	8088	3.26	1.0000	Σ	54631	115.44	0.9348	78367	64.08	0.9115

Statistics corresponding to Σ are calculated by pooling zone based ones over 35 sectors.

Table 7.3. Zone based error statistics for predicted values of consumption items.

		1976	1977	1978	1979	1980
C1	RMSE	3262	4545	4225	9089	6247
	MAPE	4.55	7.92	6.06	9.78	10.24
	CORR.	0.9988	0.9974	0.9971	0.9958	0.9945
C2	RMSE	23994	35720	56534	64021	75732
	MAPE	2.45	4.44	6.10	7.30	8.51
	CORR.	0.9981	0.9966	0.9920	0.9904	0.9873
C3	RMSE	1311	3179	4750	5894	4694
	MAPE	9.33	14.51	25.48	22.12	22.27
	CORR.	0.9996	0.9991	0.9976	0.9956	0.9970
C4	RMSE	3179	2482	3563	4665	5063
	MAPE	2.65	2.76	3.59	3.89	4.23
	CORR.	0.9992	0.9993	0.9990	0.9982	0.9974

little decline from 0.93 in 1976 to 0.91 in 1980, the MAPE, on the other hand, even shows some improvements during that period. In this regard, we might say that our model produces rather stable results in general, as far as its flow analyzing portion is concerned. However, it cannot be denied that fairly large errors, in terms of MAPE, are observed for Sectors 15, 27 and 32 (Public works). This stems from the fact that most of their productions are defined to be captured as capital formations in Japanese input-output tables, and thus, only small fractions of productions come under the jurisdiction of the production distribution model in those sectors. Another reason is the conceptual discrepancy between income and construction statistics on which the data of capital formations and productions are respectively based. That is, while the productions are calculated on the domestic basis, bound to the places of investments, in the model, their observations are accounted by the places of establishments who do the works. Incidentally, such a discrepancy appears to be decreasing with time. Besides public works, 02 (Mining) shows higher errors, but the sector is not significant in the Region as it constitutes only 0.25 % (1976) to 0.16 % (1980) of total productions, mostly coming from quarrying as mentioned before.

With a few exceptions, other sectors demonstrate MAPE of less than 50 % range, and correlation coefficients of more than 80 %. As a matter of course, it would be inevitable that the discrepancy from the observed sequences increases with the procession of simulation cycles. This is also the case for consumption items as we can easily observe from Table 7.3. However, the deterioration of predictions with time is said to be limited to the acceptable range that the correlation coefficients for all the four items maintain approximately 99 % level after 5 cycles of simulations. In general, predictions of consumption items are much accurate as the MAPE for the household consumption C2, which in particular is predominant in the sense that it accounts for as much as 80.4 % (1976) to 81.6 % (1980) of all the consumption expenditures, are limited to less than 10 % level.

Next we examine the spatial distributions of productions and the household consumption expenditures. Figure 7.3 summarizes error ratios $(\hat{X}_i^P - X_i^P)/X_i^P$ after the five years of simulations at the prefectural level. The productions are shown in five categories; (a) all sectors, (b) manufacturing sectors; 03-10, (c) non-manufacturing private sectors; 11-35 excluding those classified into the following two categories, (d) public and government services; 16, 17, 28, 29, 33, and 34, and (e) construction sectors; 12, 15, 20, 27, and 32. At the regional level, errors are confined to less than 10 % for productions other than (d). However, at the prefectural level, considerable margins of errors are observed. In particular, the construction sectors experience the largest margin ranging from -36 to 73 %, but this would be explained by reasons mentioned in connection with Table 7.2. Generally speaking, values in Tokyo tend to be underestimated, which are to be compensated by overestimations in surrounding

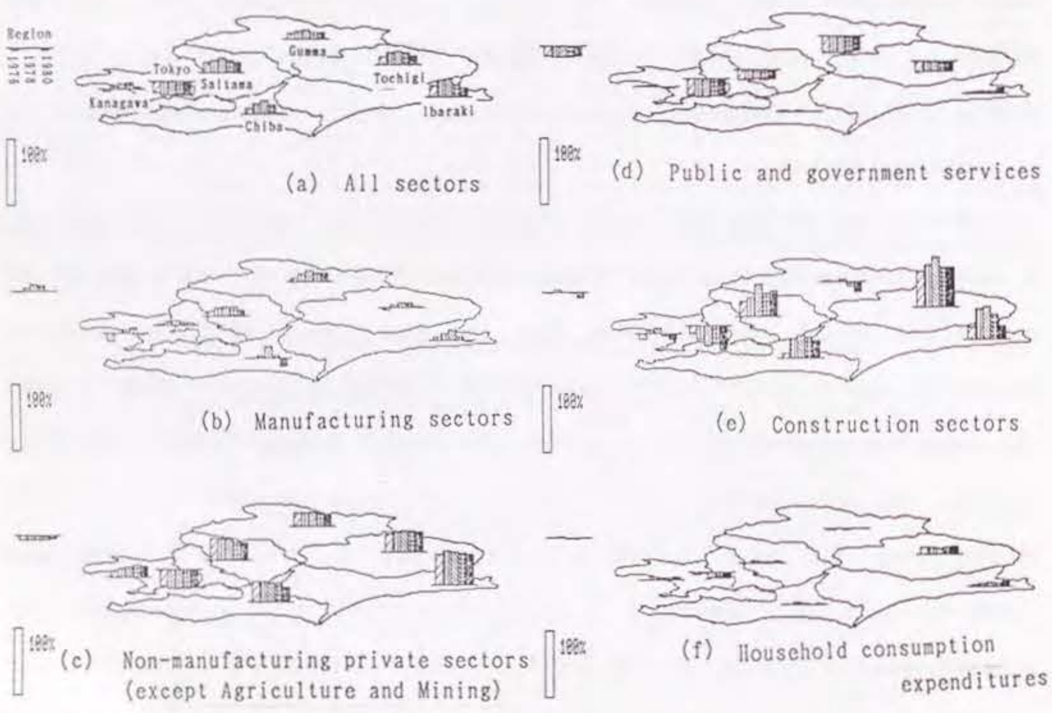

Figure 7.3. Rates of errors in prefectural allocations of productions and household consumption expenditures through the flow simulations (1975-80).

prefectures. As productions in Tokyo and Kanagawa are predominant, errors in real amounts in other prefectures are not as large as they appear to be. In many sectors, though higher errors are observed in the midst of simulations, those in the final year are relatively lower. Thus we may safely state that the errors are not accumulating through the simulations as far as the prefectural productions are concerned. On the other hand, fairly accurate predictions are obtained for the household consumption expenditures with around 8 % of errors at most at the prefectural level.

Figure 7.4 shows the same ratios at the zonal level for the southern four prefectures in 1980. The error ratios would naturally increase with further subdivision of the Region. While those for the total productions are within the range of -32 to 21 %, the public and government services reach the maximal error of 104 % in Zone 506 (Ichihara) of Chiba Pref. facing Tokyo Bay. Errors in the non-manufacturing private and construction sectors are ranging from -38 to 52 % and from -44 to 58 %, respectively,

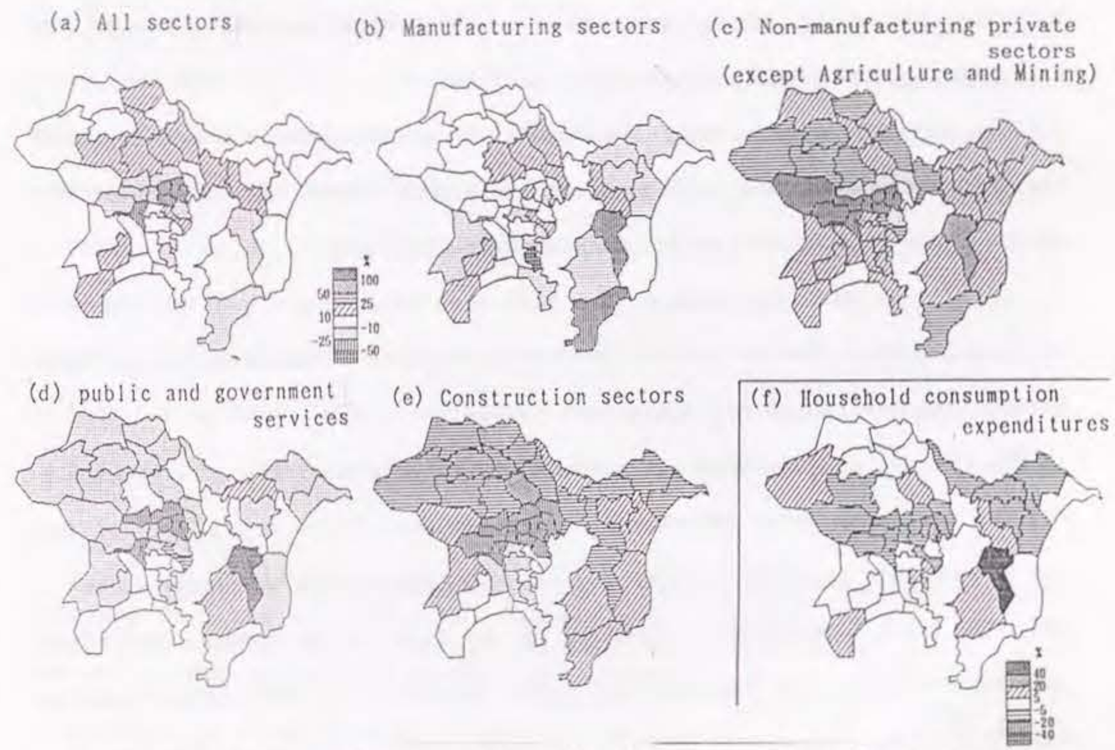

Figure 7.4. Rates of errors in zonal allocations of productions and household consumption expenditures through the flow simulations (1980).

where only a few zones are within the ±10% range. Concerning those sectors, we can observe a dichotomic classification of zones in terms of errors, where the zones belonging to Tokyo tend to be underestimated. Unlike the error ratios at the prefectural level, those associated with the household consumption expenditures are not particularly small in terms of their range, between -20 and 45 %, but most of the zones stay within the 20 % range with only 3 exceptions.

7.3. Flow and Stock Simulations[3)]

Next we discuss the results from the flow and stock simulations which cover the activity and location model and a part of the regional frame model as shown in Figure 7.1. In particular, the following two remarks made in previous chapters apply to the predictions in the location model.

i) While the bid price functions are determined in terms of existing allocations of land ρ_i^c, the new acquisitions are calculated from the probabilities concerning the increments r_i^c, which are derived through the difference operations in eqs.(2.7b) and (2.8b).

ii) The parameters concerning the demolition probabilities are calculated for the seven categories, but in practical applications, they are calculated for individual activities as mentioned in Section 6.6.

Similarly as is the case in the flow simulations, the test is conducted under several limitations as well as a number of measures to prevent drastic changes, which are summarized below.

i) The C-level computations are confined to the southern four prefectures.

ii) The variables to be determined in the regional frame model, except for the consumption items C1 through C4, are substituted by the observed ones.

iii) The input coefficients included in the formulas to predict the stock related variables are replaced by those obtained from the 11-prefectural tables.[†3]

iv) A certain number of stock variables, which are explained by the land use data, cannot be determined endogenously in the northern three prefectures. They include the employments E_i in 20 sectors (Sectors 11, 13, 14, 16-19, 21-26, 28-31, and 33-35), the non-housing capital formations ΔK_i, the housing constructions ΔH_h, along with the demolition probabilities ν_i.

v) The demolitions in any single year are confined to 10 % of the existing stocks, viz. $\nu_i \leqq 0.1$.

vi) Similarly, the land acquisitions are confined to 10 % of the existing vacant land in addition to all the land newly released by demolitions, viz. $\Sigma_i r_i \leqq (0.1LA_{-1}+\Sigma_i \nabla L_i)/LAD$.

The first point, which is the same as in the case of flow simulations, as well as the fourth point comes from data limitations. The second point suggests a difference from the flow case in dealing with the regional values of net increase in stocks J_i and net exports FM_i. Namely, we here regard those values as being exogenous to the model in order to avoid the errors accrued from mis-specifying them, while the results in the previous section are obtained by determining them endogenously. The fourth point stems from the fact that the land use data for the northern three prefectures, which are required as the initial values to the model, are not available. And the last two points are introduced to smooth out the predictions so as to avoid drastic changes in land use. Naturally, such measures are not desirable, but they are necessitated by a number of expedients to overcome data limitations, including the difference approximations for calculating the incremental probabilities r_i, and are expected to fill in the discrepancies between the model and the reality.[†4] Such

†3. While all the model parameters are estimated using the coefficients obtained from the 11-prefectural tables, those modified to meet the 7-prefectural configurations through the nonsurvey method in Section 3.4 are basically used in actual simulations. However, as the location model includes many nonlinear formulas, we employ the original coefficients when predicting the stock related variables. In particular, the input coefficients affect the location probabilities through exponential formulations, and their sensitivity prevents us from using the modified ones unless the relevant parameters are re-estimated to fit them.

measures can also be found in the NBER model for residential locations,[4)] where the land for housing construction in any single year is confined to 10 % of the available land in each zone.[5)]

Table 7.4 summarizes the RMSE defined by RMSE = $\sqrt{\Sigma_{d,i}(\hat{X}_i^d - X_i^d)^2/m \cdot n}$, and the correlation coefficients concerning the spatial distributions of productions, where the statistics are based on the pooled data over the sectors and the zones, which may be either of the prefectural or municipality level, with m denoting the number of sectors. The table enables us the comparisons between the simulation results concerning flow aspects and those concerning both flow and stock aspects, where two sets of results are shown for the flow case. One is designated as the case of *flow A*, which corresponds to the test conducted in the previous section. The other is called the case of *flow B*, where the regional values of J_i and FM_i are substituted by the observed ones, in order to facilitate the direct comparisons with the flow and stock simulations discussed here.

In practice, no significant changes can be found between two types of flow simulations, and thus, it would suffice to refer to the case of *flow B* when assessing their performance. As the flow and stock simulations

Table 7.4. The sectorial means of RMS errors and correlation coefficients concerning local productions, X_i^d.

Measures	Kind of tests	1976	1977	1978	1979	1980
RMS errors in	flow A	212410	239640	262280	264910	289240
P-level zones	flow B	210730	238840	262010	264300	288880
(million yen)	flow & stock	—	243000	265860	267140	298150
RMS errors in	flow A	54631	58817	64402	71076	78367
C-level zones	flow B	54366	58691	64356	70914	78289
(million yen)	flow & stock	—	54268	55416	56870	68089
Correlation	flow A	.9348	.9207	.9149	.9127	.9115
coefficients in	flow B	.9347	.9207	.9149	.9126	.9114
C-level zones	flow & stock	—	.8981	.9023	.8963	.8867

†4. The average number of activities which violate the restriction v) ranges from 3.5 to 5.2 in each zone, which constitutes 10 to 15 % of all 34 locating activities. On the other hand, the number of zones which violate the restriction vi) varies from three to nine, including the highly utilized areas centering about the Ward Area in Tokyo Metropolis.

involve more transformations than the flow simulations, the greater discrepancies from the observed data are normally expected for the former. However, Table 7.4 indicates that the RMSE for the C-level zones are even improved despite the extension of the scope of the model where the variables are predicted endogenously. Thus we might say that the stock analyzing portion of our model would be free from accumulative errors. Meanwhile, the effective simulation cycles in terms of stock variables starts in 1977, and after four cycles of the flow and stock simulations, the zonal RMSE and correlation coefficient experience a 25 % increase and 1.3 % decrease, respectively. As a matter of course, repetition of such cycles would necessarily carry divergence from the observed sequences, but it is comparable with the flow case, where the RMSE increases by 33 % and correlation coefficient decreases by 1.0 % during the same period.

The model performance concerning the stock variables and their net changes are summarized in Table 7.5. Both are indicated in terms of correlation coefficients, while the former are evaluated at the final year of simulations, 1980, and the latter are evaluated by the cumulative changes over the four-year period. The table lists the results concerning the zonal employments E_i^c, population N^c, non-land assets in manufacturing

Table 7.5. The correlations of stock variables.

	Stocks in 1980	Changes 1976-80		Stocks in 1980	Changes 1976-80		Stocks in 1980	Changes 1976-80
E_1	.9996	.9807	E_{19} *	.9742	.1293	K_3	.9692	.7675
E_2	.9672	.5607	E_{20}	.8833	.1658	K_4	.9945	.8894
E_3	.9804	.7200	E_{21} *	.9511	.6172	K_5	.9872	.2462
E_4	.9756	.7761	E_{22} *	.9607	.5535	K_6	.9683	.3318
E_5	.9786	.6461	E_{23} *	.9928	-.4830	K_7	.9762	-.0466
E_6	.9819	.7579	E_{24} *	.9925	.6208	K_8	.8257	.3493
E_7	.9607	.4078	E_{25} *	.9851	.8165	K_9	.9655	.6334
E_8	.9602	.3635	E_{26} *	.9982	.5578	K_{10}	.9905	.7136
E_9	.9505	.3835	E_{28} *	.9670	.0353			
E_{10}	.9397	.5943	E_{29} *	.9830	.4278	H_1 *	.9936	.5614
E_{11} *	.9419	.3462	E_{30} *	.8511	.2081	H_2 *	.9938	.4081
E_{12}	.9447	-.0721	E_{31} *	.9918	.1701	H_3 *	.9877	.6403
E_{13} *	.9301	.6018	E_{33} *	.9971	.8568	H_4 *	.8889	.5667
E_{14} *	.9702	-.8667	E_{34} *	.9919	.5899	H_5 *	.9056	.0063
E_{16} *	.8395	-.0497	E_{35} *	.9675	.7085	H_6 *	.9145	.0568
E_{17} *	.9790	.7846	E_c	.9671	.1983			
E_{18} *	.9695	.4800	N	.9617	.4085	VL *	.9866	.3062

sectors K_i^c, number of housing units H_h^c, and the land prices VL^c, among which those with asterisks (*) represent the values corresponding to 48 zones in the southern four prefectures in conjunction with the points i) and iv) mentioned above.[†5] We might say that the results are satisfactory in general as far as the stocks are concerned, but only fair to poor fitness is observed as to their changes. In particular, while the shaded values indicate the correlation coefficients less than 30 % level, the predicted values for some variables are even negatively correlated with the observed ones.

Finally, we examine the spatial distributions of productions and household consumption expenditures. Figure 7.5 corresponds to Figure 7.4 in the flow case, where the error ratios in 1980 are shown in seven to

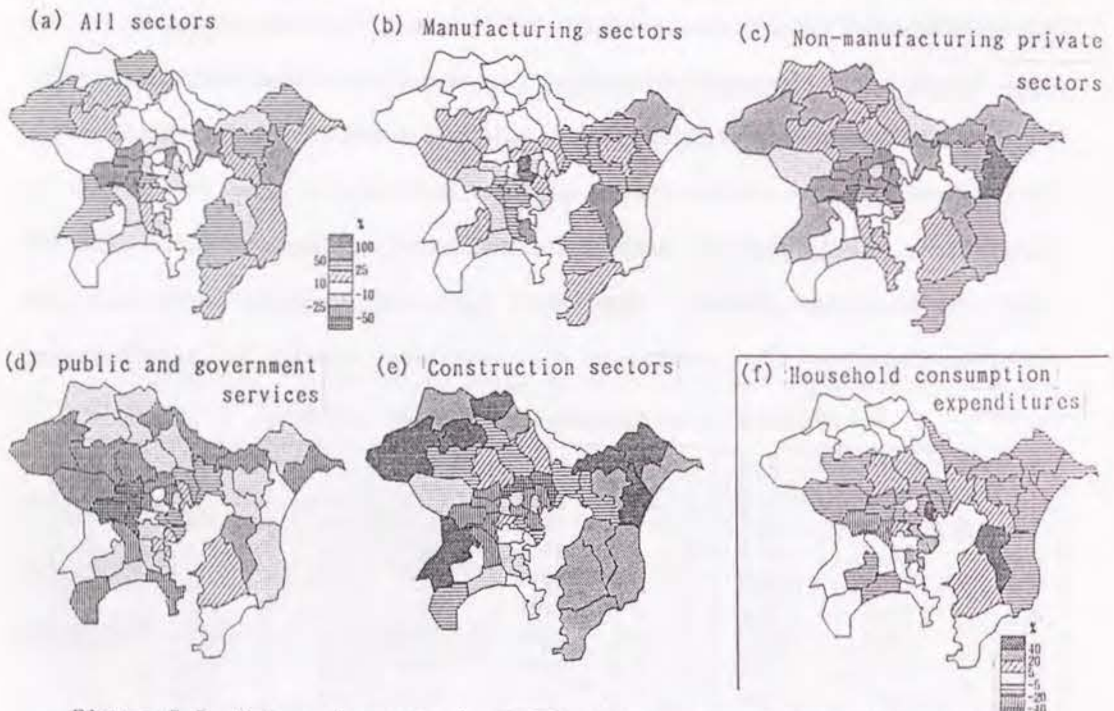

Figure 7.5. Rates of errors in zonal allocations of productions and household consumption expenditures through the flow and stock simulations (1980).

†5. Despite the point iv), the manufacturing stocks K_i are not accompanied by asterisks in the table. While it is impossible to fully calculate these variables in the northern prefectures, eq.(6.15b) still reflects a "model" concerning capital depreciations. In this respect, the predictions for K_i slightly diverge from the observed values.

eight grades for the C-level zones. The errors associated with the total productions range -35 to 62 %, which is naturally wider than in the previous case. While those sectors belonging to the tertiary industry are accompanied by at most 100 % of errors, the manufacturing and construction sectors experience much wider margins of errors, viz. from -43 to 135 % and from -56 to 165 %, respectively, as compared with the flow case. However, the errors associated with the former are not so severe when we consider the cumulative distribution of error ratios. Namely, with only two zones in Tokyo (Zones 605 and 606) recording errors over 100 %, 42 % of zones are within ±10 % range, and such a proportion will be increased to 67 % if we allow errors of ±20 % range.

On the other hand, the errors in construction sectors are much severe in the sense that the proportions of zones, whose errors remain within those ranges, are merely 10 and 17 %, respectively. However, the fact that the seven zones with errors over 100 % level are located mostly in mountainous and/or remote areas would give us a little comfort since only limited amounts of productions would be observed in those areas. And the conceptual discrepancy in terms of statistics, mentioned in the previous section, would certainly contribute to those errors. Meanwhile, the nonmanufacturing private and construction sectors are likely to be underestimated in Tokyo and its vicinities similarly as is the case in the flow simulations. And the errors associated with the household consumption expenditures are quite limited, ranging between -24 and 44 %, which are comparable to the flow case.

Probably, these results yet appear to be satisfactory, but it would be somewhat unfair to criticize the error ratios at the smaller spatial levels as the regressions tend to sacrifice the goodness of fit in zones with smaller amounts. In other words, when we recall the fact that the pooling correlation concerning the zonal productions corresponding to the figure reaches about 89 %, it would be possible to imagine the actual magnitudes of errors are not so large as one might be impressed from those ratios. And this observation would point out a myth associated with the aggregative measures like the correlation coefficients.

The predictions in modern location models tend to be made in terms of the stock variations rather than the whole stocks.[6)] Although the evaluations based on the latter guarantee better correlations, it is naturally desirable to evaluate their performances in terms of variations to emphasize dynamic characteristics of the models.[†6] On the other hand, we might say that the present measures for evaluations, such as the RMSE, MAPE or correlation coefficients, are still not that fair in the sense that they are based on the all-or-nothing type evaluations. Suppose it is predicted that a location of an activity is to occur in a particular time and place, and the actual location occurs either in the next year or in the adjacent zone to those predicted. Then none of the above measures will give evaluations on those close predictions, even though they are far better than nothing when we consider the degree of freedom associated with a location problem. In particular, if the predicted time deviates from the observed by one or two years, the predictions might be called almost correct in a long-run as far as the future stocks are concerned. In this regard, it is necessary to develop a measure which would grant certain evaluations to those close predictions.[†7]

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†6. For example, Abe reported the correlation coefficients concerning zonal employments and their variations in his Osaka model for a simulation step of five years,[7)] where the latter are lower in all sectors. However, not many simulation models report the variational statistics, except for those can be categorized as the micro simulation models.[8)]

†7. Miyamoto *et al.* has proposed a measure called the *spatial fit indicator* (SFI) based on the cost associated with a transportation problem to rectify the errors.[9)] While that measure only considers the cross-sectional evaluations, the efforts to formulate such a measure are quite important. And for the purpose, the knowledge derived from the ordinary and spatial autocorrelations would be of assistance.[10)]

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CHAPTER 8

CONCLUSION

The primal objective of the study is to formulate a comprehensive simulation model on metropolitan land use. The model is formulated as a recursive dynamic model, which comprises three major model blocks; the regional frame model to determine the macroscopic frameworks in the study area during each period, the activity model to determine the spatial allocations of flow aspects of metropolitan activities, which are based upon the stock allocations to be determined in the location model. These model blocks are linked together to form a dynamic system in the way that both the location and activity models are repeated consecutively under the control of the regional frame model. Although the modeling techniques employed here are rather modest, the individual formulations are carefully examined to maintain consistency with the existing theories and efficiency in terms of data utilization. Nevertheless, it is possible to refer to the three level input-output (3LIO) model and the aggregative application of the random bid price theory as being the major analytical schemes in our model, for analyzing flow and stock aspects of metropolitan activities, respectively.

Although there exists no unique way to count the exact number of equations associated with a model, our model roughly comprises 143 formulas to be estimated.[†1] However, the specifications fully depend on the data set

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†1. There are roughly three causes which lead to such ambiguity. For instance, the parameters associated with the location probabilities are determined simultaneously for all locating activities. As this expression contains 34 bid price functions and the reservational one, the number of equations to be estimated would be either one or 35. Namely, i) existence of logit type functions which include the a number of functions corresponding to respective activities is the first cause. Other causes are; ii) existence of some collective expressions which are applied to a number of sectors, such as the demolition probabilities, and iii) existence of formulas which could be applied to different spatial levels, such as the distribution functions for consumption items.
The number quoted is obtained by counting the functions in the first

prepared in the sense that it is impossible to use unavailable variables even if they are known to be useful in explaining the real-world phenomena. For the purpose, the data are collected for the Tokyo Metropolitan Area consisting of Tokyo and six surrounding prefectures between years 1975 and 80. It is important to note that these data, except for those related to land use, are compiled exclusively from various statistics published periodically by the national or prefectural governmental organizations. This requires, on one hand, to interpolate all the data for every year in-between owing to the differences in years considered by individual publications, and guarantees the transferability of the model to other parts of the nation as it demands no supplementary surveys, on the other. And the fact that the data are compiled on the annual basis enables us to operate the model also on the same basis.

In light of its objectives, it would be quite natural that most of the study is devoted to the descriptions of individual formulas in the model. Nevertheless, it is still necessary to spend Chapters 1 through 3 for discussing some preliminaries. In particular, *Chapter 1* briefly reviews the histories of location theory and the operational models. It was pointed out that there exists a gap between the macro-econometric models focusing the national economy and the non-economic approach based upon needs to predict the locations in the relatively narrow metropolitan area. In this connection the objective is stated so as to formulate a metropolitan simulation model which is consistent with the existing theories, and thus, managed to narrow such a gap to some extent. And the discussions in the succeeding chapters could be summarized as follows.

In *Chapter 2*, we define configurations of a metropolitan simulation model to be formulated, and the analytical schemes which are consistent

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(continued)

category by individual activities while counting those in the rest of the categories collectively by the number of equations subject to parameter estimations. Accordingly, the regional frame, activity, and location models account for 12, 34 and 97 expressions to be estimated, respectively.

with such configurations are discussed accordingly.

i) While many operational models inherit the Lowry tradition, the locations of certain activities are not precluded from the model. Thus no prespecified ordering is assumed as far as stock allocations are concerned.

ii) Leontief's balanced input-output (BIO) analysis provides an analytical tool which makes the spatial and sectorial minuteness of our flow analyses compatible with the deficiency of data. The classification of activities required by the BIO model is found to be consistent with the administrative principle in Christaller's central place theory.

iii) There are two ways to view the locating processes; the agents choose their locations in accordance with the utilities, and the land owners choose the locators in accordance with the offers bidden by the agents. In the context of disaggregative behavioral models, the former corresponds to the random utility theory and the latter to the random bid price theory.

iv) As the former is associated with the problem of violating land constraints, we consider to apply the latter in the aggregative context. It is noteworthy that the bid prices therein are theoretically different from those in Alonso-type models. In the aggregative context, however, it is possible to establish a relationship between those two types of bid prices.

v) The model as a whole is formulated as a recursive dynamic model. The two model blocks, the activity and regional frame models, are basically econometric, where the dynamism is expressed in terms of lagged variables.

vi) The bid prices reflected in the aggregate location probabilities are estimated with the static land use data. In practice, it is desirable to express such probabilities in terms of increments, which can be achieved by the difference transformations, based on the dynamic theory of urban land use, on the static ones.

These configurations are materialized through discussions in *Chapter 3*, where the basic construction of the model along with a few problems relevant to such materialization are considered.

i) While the wards, cities, townships and villages serve as the minimal statistical units, the zones which are comparable to the old counties are employed as the minimal spatial units in the model. Accordingly, the hierarchy of the study area comprises three levels; those zones, prefectures, and the Region as a whole.

ii) The industrial activities are classified into 35 sectors, which are categorized into three levels corresponding to the spatial hierarchy. The independent clerical activity and the distinction among public activities corresponding to the jurisdictional levels characterize our classification.

iii) The major exogenous variables to the model are the regional population and the interest rate, and the rest of the macro variables, such as the regional employments and the final demand items, are determined in the regional frame model. The location model, to determine the spatial allocations of stocks, precedes the activity model in charge of flow aspects. The former comprises five submodels, and the latter combines the 3LIO model and the distribution models for productions and consumption items.

iv) While it is desirable to evaluate monetary variables in real terms, the commodity based inflators can be calculated from the two sets of gross prefectural expenditures, nominal and real, using the input-output tables. The method is capable of dealing with any industrial classification.

v) The input coefficients obtained from the tables for the 11 prefectural region are found to be inadequate to our study area. Accordingly, a nonsurvey technique to adjust the original coefficients with the configurations of our Region is proposed. It can be divided into two parts; viz. the modifications focusing on the intra-regional trades and those to simultaneously process the input coefficients and the final demand converters. The empirical results suggest that our method is effective in improving the errors in projected productions in certain sectors.

vi) The deficiency in the degrees of freedom associated with individual model formulas would require us to estimate the parameters at the other spatial level different from the one for predictions. It is found that the transferability is guaranteed for linear expressions, but log-linear expressions may be transferred only when they are distributive.

The succeeding three chapters are devoted entirely to the descriptions of individual model blocks, and *Chapter 4* is devoted to the descriptions of the activity model which is based on the 3LIO model.

i) The 3LIO model is formulated as a three level rendition of Leontief's BIO model. However, the former differs from the latter in the way to deal with the intra-regional trades. The final demands are given on the item basis, which are then distributed over commodities with the final demand converters. This simultaneous determination of final demands for all the commodities enables us to consistently calculate the trade imbalances.

ii) The distribution models for consumption items are formulated as the linear equations on the per capita basis to maintain their invariant nature w.r.t. spatial aggregations. As income transfers among zones cannot be ignored at the lower spatial levels, the formulations to make such transfers compatible with the spatial aggregations are introduced by means of the first-order Taylor expansions.

iii) The distribution models for productions are required for R and P-level activities. The production functions are estimated at the prefectural level, but they could be transferred to the zonal level due to their distributive nature.

iv) Some of the distribution functions for consumption items reflect the concurrent value added to be determined through the input-output computations. Hence, a procedure to simultaneously determine both productions and consumption items is presented.

The regional frame model is formulated in *Chapter 5*. As the formulas for consumption items are prespecified in accordance with those in the activity model owing to their consistency w.r.t. spatial aggregations, the rest of the final demand items as well as the sectorial employments are to be formulated.

i) It must be noted that some of the regional values, such as the regional productions, cannot be determined independently. Namely, it is appropriate to consider the 3LIO model corresponding to the regional level as being a part of the regional frame model.

ii) The investment items are formulated as standard econometric expressions. Unlike other final demand items, the net increase in stocks and net export could be either positive or negative. Hence, they are calculated in two steps; their gross amount is first calculated, which are then distributed over the commodities through the expressions which are consistent w.r.t. commodity aggregations and allow mingled signs of predictions. The sectorial employments are also calculated in two steps.

iii) The parameters in formulas in the regional frame model, excluding those to predict values on the commodity basis, are estimated at the prefectural level to secure sufficient degrees of freedom. Thus the formulas for the parameter estimations are not necessarily the same as those used for predictions as the transfer terms cannot be ignored at the lower spatial levels. Those terms are selected to maintain the consistency w.r.t. spatial aggregations.

iv) There might be a case where dependable predictions for those regional statistics, called the standard values, are given from outside the model. As it would be beneficial to utilize them to improve our predictions, we consider to incorporate them in the Taylor expansions of the original formulas. However, it must be noted that some of those values cannot be determined independently. Thus the relationships to be satisfied among them are clarified.

Chapter 6 is devoted to the descriptions of the location model, where both demolitions and locations are assumed to take place consecutively at the beginning of each period. The resulting allocations of stocks are maintained throughout the period to provide the arena for the flow aspects of activities. Lastly, the posterior land prices are calculated as the indices to represent the land market in the period.

i) As our major concern is on the urban land use, this block focuses on the locating activities which are defined as those competing over urban land area. Thus the most important function in the model would be the one to allocate urban land to the 34 locating activities, including six housing types. And the spatial distributions for the rest of the activities are assumed to depend on their allocations.

ii) Those allocations are made in accordance with the location probabilities based on the random bid prices through the basic location submodel. The bid price function for each locating activity is defined as a linear function of various potentials. And the parameters associated with those bid price functions, including the reservational one, are estimated simultaneously by a nonlinear least squares method which incorporates the log-linear regressions corresponding to respective activities.

iii) The potential variables in each bid price are chosen systematically to attain stable parameters, but only the land price in the previous period is found to be significant for explaining the reservational one. The land acquisitions calculated from the location probabilities on the incremental basis are then converted to the location entities, such as industrial assets and housing units.

iv) Those increments are counted in the existing amounts of stocks through the stock accounting submodel. Unlike the industrial assets or the housing units, the whole employments are calculated each period due to their mobilities as compared with those fixed capital.

v) The auxiliary location submodel allocates the variables which are dependent upon the results of the aforementioned submodels as well as the employments in the non-basic activities. The former category includes the investment items other than manufacturing, and the latter category includes the agricultural, mining and construction employments.

vi) The commuting distribution submodel transforms the employments at job sites into the populations at residential sites by means of a doubly constrained gravity model operated on the cross-sectional basis. When we can assume that the households' foresight is much shorter than that of developers, it is possible to consider the households' behavior being subordinate to the developers'.

vii) The population and employment densities are significant in explaining the posterior land prices, which are calculated after all the stock allocations are settled. They will provide important information to the demolition submodel in the succeeding period.

viii) The demolition submodel is executed at the outset of the present model block to calculate the demolitions occurred to the existing stocks. They are determined through the binary logit models to assess the demolition probabilities. The locating activities are classified into seven categories, each of which shares the same formulation.

The model described above is tested in *Chapter 7*. Two types of test simulations are conducted to confirm its operationality, but those tests may be called quasi-final in the sense that only a part of the variables to be determined in the regional frame model are endogenously obtained. The simulations are carried out over the same area and period as those used for estimating the model parameters, where the values in 1975 are considered to represent the initial state.

i) All the stock variables are exogenously given in the flow simulations. And their results are used as a reference to the flow and stock simulations which incorporate the location model. Due to the lack of initial values, the observed values are substituted for some stock variables in the northern three prefectures.

ii) As far as the productions are concerned, no proof of increased errors has been found when the location model is incorporated in the flow and stock simulations, since their RMSE, in terms of spatial and sectorial distributions, are comparable with those in the flow simulations. And in both cases, the spatial allocations of productions in construction sectors are associated with a large margin of errors, which may be caused by their investment oriented nature and the conceptual discrepancies in statistics.

iii) While a fairly good fit is observed in terms of correlations with the

stock variables, those associated with their variations are not necessarily satisfactory. However, this is partly due to the all-or-nothing nature of the measures used for evaluations, and in return, suggests the need for new measures which could appreciate the close predictions.

Every operational model would be obtained through a sequence of compromises between theories and data. In this regard, the model presented here could not be complete in the sense that the formulations and the relevant parameters are selected on the ground of a particular set of data. However, we believe that the overall structures of the model are more important rather than the individual formulations. Namely, while many models concentrate on the locations in particular sectors or land use in general, what we intend to construct here is a comprehensive metropolitan simulation model which covers both flow and stock aspects of *all* the economic activities in a metropolitan area. The model is designed to be well-balanced in the sense that it maintains the minuteness and operationality compatible with its detailed classification of activities while observing the consistency with the existing theories. In those respects, it is hoped that the primal objective of the study has been satisfied to some extent.

Naturally, further refinements of the model are always desirable together with continuous efforts leading to the accumulation of data. Since our model is designed to be capable of operating solely with information available in published statistics, it would be meaningful to examine its transferability. An exception is the deficiency of data concerning land use structures even though such data are recently available on the mesh basis. Namely, the classification of land employed in those mesh data is not detailed enough for our purposes, and their publication is still sporadic. In addition, although the rest of the data are to be compiled from combining various statistics, the compilations require rather complicated procedures. Hence, it would be quite beneficial to construct a manual leading to the standardization of data compilations.

APPENDIX

SELECTED DATA TABLES

Table A.1. The regional input-output table (1975; Part 1).

		1 Agriculture, forestry and fisheries	2 Mining	3 Food and beverages	4 Textile	5 Wooden and paper products	6 Printing and publishing	7 Chemical products	8 Metal products	9 Machinery	10 Other manufacturing	11 Electricity and gas	12 Non-residential building
1	Agriculture, forestry and fisheries	313757	782	2228512	126705	322555	1603	24124	11247	17822	54769	2406	7880
2	Mining	2255	1092	4867	1616	8202	1557	2556537	285899	15221	217947	284959	24944
3	Food and beverages	338338	728	1080527	3118	7696	573	72368	9936	15189	7166	2423	7902
4	Textile	21135	833	12946	835926	23274	11212	12391	18985	47973	94808	3904	24839
5	Wooden and paper products	33811	1353	86699	7781	996038	405514	137928	44649	183298	198494	6715	241638
6	Printing and publishing	2682	1080	21500	10496	136328	425173	20643	18625	61162	17348	6627	7757
7	Chemical products	222392	17839	135469	131198	88004	60369	1902342	555501	244459	572124	331614	44967
8	Metal products	16140	6656	120677	20104	78685	10096	79804	4800962	2276211	121612	71470	727291
9	Machinery	19978	3991	29283	7310	18699	3434	34396	60145	5138561	25227	9008	155261
10	Other manufacturing	33041	2068	131386	24786	44699	25270	130512	94507	714670	664159	17568	401194
11	Electricity and gas	11831	6312	41629	21082	71605	15638	149418	268192	154670	91841	24844	27313
12	Non-residential building	6573	999	9450	3814	4667	1841	15615	16481	20434	7476	41959	5210
13	Far-flung transportation	15597	1676	71774	16975	33328	24463	71077	82081	98023	55575	17678	39846
14	Wholesale	44442	4773	345231	92013	154029	96397	187666	251558	735702	235354	29564	221174
15	Public works of R-level	138	13	110	63	45	38	232	256	288	104	929	16
16	Community services of R-level	406	173	6861	1644	2481	1187	68360	13398	163728	9351	4208	4408
17	Government services of R-level	0	0	0	0	0	0	0	0	0	0	0	0
18	Clerical business	2466	30605	7554	5202	112806	275502	240415	316019	1056406	184540	158069	172421
19	Water supply	130	177	9213	1063	3421	202	14113	7082	10965	4067	1633	3042
20	Residential building	0	0	0	0	0	0	0	0	0	0	0	0
21	Passenger transportation	13184	8875	29153	13274	20115	19047	41120	52756	108987	42964	14810	45531
22	Freight transportation	66369	94446	78959	19607	43555	19896	71687	86723	121705	100250	22724	110437
23	Communication	2760	1929	14064	9684	14701	6012	45835	35294	94572	24448	5483	18355
24	Finance, insurance and real estate	91896	21496	103056	120382	106831	68364	308174	236018	543263	113267	111811	89153
25	Business services	39854	8158	237103	98875	85642	107916	281918	148082	566244	181195	73061	139549
26	Entertainment	222	177	1999	446	1160	4518	2351	2262	3363	1268	567	1936
27	Public works of P-level	45	4	36	21	14	12	75	83	94	33	302	5
28	Community services of P-level	1765	698	90982	4550	5342	3342	21136	21412	53034	30893	4160	10248
29	Government services of P-level	0	0	0	0	0	0	0	0	0	0	0	0
30	Retail	47624	6092	37837	12725	21074	9853	25848	33765	77211	37424	8068	47429
31	Personal services	572	452	5106	1142	2963	181	6007	5784	8604	3242	1451	4944
32	Public works of C-level	110	11	87	50	36	31	184	204	229	82	738	13
33	Community services of C-level	509	373	4239	958	2457	182	4996	4837	7234	2698	1211	4078
34	Government services of C-level	0	0	0	0	0	0	0	0	0	0	0	0
35	Sewage and waste management	152	183	1458	911	1318	1449	8178	2335	7399	2112	941	1608
36	Intermediate inputs	1350175	224044	4947766	1593521	2409772	1600674	6535451	7485077	12546723	3101841	1260905	2590394
37	Scrap metal	326	40	645	219	319	229	1960	175764	-91989	-1177	195	-1753
38	Consumption expenditures outside households	15357	12356	118358	39227	64172	89742	187017	131073	374062	101558	31183	110347
39	Compensation of employees	238790	60565	618638	459216	454811	407740	373268	1057432	2876662	790930	115222	580363
40	Operating surplus	1450029	57951	471853	58976	176026	165397	344967	551667	1265806	307704	223079	581852
41	Depreciation of fixed capital	270406	48130	188917	76451	134397	65578	362272	467462	815871	266780	256329	145122
42	Indirect taxes	80733	10843	619114	22861	33301	24948	521150	90167	429446	91594	117878	40610
43	(Less) Current subsidies	-62829	-3383	-348379	-1466	-1746	-1256	-4441	-5312	-30560	-2503	-1151	-2159
44	Total gross value added	1992812	186502	1669146	655484	861280	752379	1786193	2468253	5639297	1554888	742736	1454382
45	Production	3342986	410546	6616911	2249005	3271053	2353053	8321644	9953330	18186020	4656730	2003640	4044776

Table A.1. The regional input-output table (1975; Part 2).

		13 Far-flung transportation	14 Wholesale	15 Public works of R-level	16 Community services of R-level	17 Government services of R-level	18 Clerical business	19 Water supply	20 Residential building	21 Passenger transportation	22 Freight transportation	23 Communication	24 Finance, insurance and real estate
1	Agriculture, forestry and fisheries	3871	5130	1971	3019	125	0	413	4563	2966	1640	2009	13615
2	Mining	9626	5048	27756	1435	300	0	188	44858	9059	1475	4357	7990
3	Food and beverages	4276	3971	462	2227	247	0	558	4927	2090	813	2272	14907
4	Textile	18238	24705	2031	3033	5777	0	542	34454	9491	6111	6105	14082
5	Wooden and paper products	19440	99459	4856	15612	4812	0	699	728010	13164	3862	11818	31592
6	Printing and publishing	6710	33014	1021	70582	6531	0	958	6233	6679	3480	16590	74810
7	Chemical products	242326	25883	17834	12300	16392	0	4458	46047	775474	443262	9423	32151
8	Metal products	50491	65647	38487	4491	3508	0	1177	521343	42471	4123	57669	33341
9	Machinery	178294	36454	6466	7453	82102	0	1753	91258	59220	4768	8217	49387
10	Other manufacturing	22498	16340	50079	20825	22322	0	1576	400670	18698	2966	11099	44619
11	Electricity and gas	58615	46882	5856	33624	2086	0	20431	17601	39501	10259	8675	46932
12	Non-residential building	15349	7465	412	9984	3809	0	10185	4067	12960	2248	2887	783406
13	Far-flung transportation	789492	81292	4808	18115	16181	0	523	43767	38178	34251	15756	28281
14	Wholesale	32045	187470	17743	17197	9045	0	1897	299410	102260	58565	18152	48174
15	Public works of R-level	301	161	3	199	84	0	225	24	273	44	37	17719
16	Community services of R-level	1846	1645	420	420	41	0	108	4125	1936	330	1483	2963
17	Government services of R-level	0	0	0	0	0	0	0	0	0	0	0	0
18	Clerical business	296057	1417518	0	0	0	0	0	0	0	0	0	0
19	Water supply	3194	1533	361	4609	473	0	24	2722	3593	2511	1509	3229
20	Residential building	0	0	0	0	0	0	0	0	0	0	0	0
21	Passenger transportation	40565	130411	4852	15341	19053	0	990	38787	77118	45477	7959	74333
22	Freight transportation	40320	90843	14781	4037	4995	0	1593	129283	93086	50398	25794	13688
23	Communication	24147	132718	2518	9987	8174	0	1019	11195	6643	9927	12337	105556
24	Finance, insurance and real estate	292333	817482	10412	55380	146877	0	8356	86625	163602	74093	41112	801674
25	Business services	79365	218911	15184	44254	29494	0	8440	106009	585884	392771	29858	359046
26	Entertainment	937	187	121	556	585	0	139	1294	434	138	553	3540
27	Public works of P-level	98	52	1	65	27	0	73	8	89	14	12	5758
28	Community services of P-level	10459	12664	795	2414	2273	0	416	8346	4667	2284	3428	20983
29	Government services of P-level	0	0	0	0	0	0	0	0	0	0	0	0
30	Retail	15637	79634	2145	18532	4676	0	1183	43866	107078	105490	8010	43499
31	Personal services	2678	490	309	1402	168	0	358	3300	1134	364	1474	9044
32	Public works of C-level	239	128	2	158	66	0	179	19	217	35	29	14086
33	Community services of C-level	24168	508	252	1150	137	0	292	2688	1391	321	1169	7506
34	Government services of C-level	0	0	0	0	0	0	0	0	0	0	0	0
35	Sewage and waste management	7924	3280	136	902	249	0	48	1418	3059	1030	959	4291
36	Intermediate inputs	2291537	3546926	232053	379302	390609	0	68801	2686917	2182418	1263050	310752	2710202
37	Scrap metal	202	745	-82	108	-544	0	23	-256	234	215	59	1063
38	Consumption expenditures outside households	66109	335174	12485	7104	31263	0	4161	121367	49389	35106	23667	168897
39	Compensation of employees	636354	1858799	134649	681852	605370	4275579	87091	869760	804488	707433	622000	2143464
40	Operating surplus	-174577	1380174	46360	896	0	0	45569	690009	154138	104003	-22459	4035521
41	Depreciation of fixed capital	285925	344191	38413	47871	34932	0	39714	116548	172430	74718	318912	1536674
42	Indirect taxes	66611	212613	3409	487	5446	0	2358	54972	31008	24457	16217	374869
43	(Less) Current subsidies	-76654	-37866	-2283	-10591	0	0	-12419	0	-58143	-6050	-2029	-69854
44	Total gross value added	803970	4093830	232971	727727	676467	4275579	166497	1852400	1153543	939882	956367	8190635
45	Production	3095507	7640756	465024	1107029	1067076	4275579	235299	4539317	3335961	2202932	1267118	10900837

Table A.1. The regional input-output table (1975; Part 3).

		25 Business services	26 Entertainment	27 Public works of P-level	28 Community services of P-level	29 Government services of P-level	30 Retail	31 Personal services	32 Public works of C-level	33 Community services of C-level	34 Government services of C-level	35 Sewage and waste management	36 Intermediate demands
1	Agriculture, forestry and fisheries	6349	4926	7432	447601	0	3882	243110	2910	29839	0	551	3898085
2	Mining	3740	1421	104892	1727	293	3437	3276	41619	3244	217	264	3881318
3	Food and beverages	7208	5722	5129	6828	0	2933	595852	632	52091	0	733	2259844
4	Textile	19395	4992	9200	5675	5163	18653	14589	2744	11608	3829	1106	1329750
5	Wooden and paper products	382191	14015	32898	14791	8371	61861	36715	6245	35044	6208	2720	3878305
6	Printing and publishing	352890	20887	5198	36572	18613	18900	12536	1459	52217	13803	976	1490081
7	Chemical products	79382	44528	38094	98903	8720	32721	45694	20617	419389	6467	7917	6734260
8	Metal products	24542	8503	285337	8349	1593	34829	26600	56120	23071	1182	1721	9622282
9	Machinery	781766	14086	65704	11717	920	15417	15427	10263	27336	683	2538	6976519
10	Other manufacturing	203690	19210	290198	11869	4888	35267	50087	74790	25809	3624	2230	3617210
11	Electricity and gas	22639	28048	20698	24998	5377	58629	120186	7757	51685	3987	7257	1526098
12	Non-residential building	11904	17074	3911	10286	12054	9721	6498	573	22313	8939	2202	1092762
13	Far-flung transportation	35891	7796	27580	11231	14199	31785	19398	6938	19286	10530	1183	1784552
14	Wholesale	220123	20065	110623	37936	4913	41093	190145	25958	108895	3644	3051	3956312
15	Public works of R-level	184	331	18	198	276	203	105	4	436	204	41	23300
16	Community services of R-level	7955	828	2836	674	0	654	807	594	1132	0	136	307141
17	Government services of R-level	0	0	0	0	0	0	0	0	0	0	0	0
18	Clerical business	0	0	0	0	0	0	0	0	0	0	0	4275579
19	Water supply	2086	3882	1787	5890	751	1099	25885	451	13106	557	372	134731
20	Residential building	0	0	0	0	0	0	0	0	0	0	0	0
21	Passenger transportation	46710	29488	27674	16795	32961	160249	56724	7067	34414	24443	3084	1304312
22	Freight transportation	54017	26483	81120	8587	8134	163662	74249	21367	13450	6032	34147	1796423
23	Communication	50802	23122	12098	8973	7251	61183	21846	3404	17338	5377	2572	811321
24	Finance, insurance and real estate	132409	67842	64728	27018	82969	397695	170311	14804	65097	61526	6002	5502060
25	Business services	215510	81474	86399	52051	33148	360634	69761	21283	90040	24580	7409	4879103
26	Entertainment	236116	61232	1347	797	521	356	2814	166	1434	388	181	334105
27	Public works of P-level	60	107	6	64	90	68	34	1	142	66	13	7572
28	Community services of P-level	15520	13293	5287	2822	776	9422	96826	1074	14097	575	1137	477102
29	Government services of P-level	0	0	0	0	0	0	0	0	0	0	0	0
30	Retail	95139	29643	9675	17671	5287	60923	136720	2657	42204	3920	2712	1201055
31	Personal services	4210	3288	3435	3649	5	1402	2353	423	14223	3	465	94620
32	Public works of C-level	147	263	14	156	219	162	84	3	346	162	32	18523
33	Community services of C-level	3502	2352	2797	1739	2	818	1766	345	4056	2	380	91115
34	Government services of C-level	0	0	0	0	0	0	0	0	0	0	0	0
35	Sewage and waste management	1197	4236	998	2066	8546	3378	15398	179	4351	6338	258	98283
36	Intermediate inputs	3017273	559139	1307093	877631	266042	1591032	2055792	332448	1197891	197282	93392	73203723
37	Scrap metal	496	169	-92	191	-546	499	434	-105	351	-405	32	87569
38	Consumption expenditures outside households	120857	49603	68778	19452	25392	132331	98302	17822	45225	18830	4382	2730148
39	Compensation of employees	1269843	386772	704023	936990	807655	1886762	1327003	193699	1870943	598915	188056	31631138
40	Operating surplus	459336	376722	268502	67924	0	1175549	585212	64143	300474	0	12938	15225762
41	Depreciation of fixed capital	173885	119648	202392	69217	21163	197190	185083	55059	167612	15693	23896	7338880
42	Indirect taxes	55020	248175	19993	5688	0	139784	182131	4790	24186	0	1749	3556611
43	(Less) Current subsidies	-3964	-2075	-6056	-22692	0	-2767	-2378	-4344	-1924	0	-173	-787443
44	Total gross value added	2075474	1179015	1257540	1076769	853664	3529349	2375786	331065	2406869	633033	230880	59782665
45	Production	5092747	1738154	2564632	1954400	1119706	5120381	4431578	663514	3604560	830315	324272	132986388

Table A.1. The regional input-output table (1975; Part 4).

		37 Consumption expenditures outside households	38 Household consumption expenditures	39 Central government consumption expenditures	40 Local government consumption expenditures	41 Private housing investment	42 Private capital formation except housing	43 Government housing investment	44 Government capital formation except housing	45 Net increase in stocks	46 Export	47 (Less) Import	48 Total final demand	49 Production
1	Agriculture, forestry and fisheries	27337	1155740	0	0	0	22920	0	822	130705	498803	-2391424	-555098	3342986
2	Mining	39	3741	0	0	0	280	0	101	-66988	22626	-3230573	-3270773	410546
3	Food and beverages	176028	4731103	0	0	0	4514	0	1626	-9606	1218712	-1765308	4357068	6616911
4	Textile	61185	1503320	0	0	0	19342	0	3750	37237	817554	-1523133	919255	2249005
5	Wooden and paper products	64829	133138	0	0	0	165316	0	39727	-27083	589834	-1572814	-807252	3271053
6	Printing and publishing	14883	280374	0	0	0	1605	0	578	29160	669281	-132910	882972	2353053
7	Chemical products	55240	438824	0	0	0	5678	0	2045	28805	2832761	-1775967	1587383	8321644
8	Metal products	34978	176930	0	0	0	137310	0	26248	46618	2942122	-3033158	331048	9953330
9	Machinery	44702	1087485	0	0	0	4137938	0	855374	-174588	9468281	-4209691	11209501	18186020
10	Other manufacturing	74666	603696	0	0	0	86356	0	32687	21523	1601311	-1380718	1039519	4656730
11	Electricity and gas	189	481983	0	0	0	187578	0	12746	46	101493	-306493	477542	2003640
12	Non-residential building	382	3951	0	0	0	2224444	0	722375	93	12024	-11256	2952014	4044776
13	Far-flung transportation	4372	535368	0	0	0	61002	0	211448	6200	1656585	-1164019	1310955	3095507
14	Wholesale	73630	1588028	0	0	0	708189	0	113853	46387	2295487	-1141129	3884444	7640756
15	Public works of R-level	0	0	0	0	0	15919	0	425805	0	0	0	441724	465024
16	Community services of R-level	105	164192	104680	521535	0	755	0	272	25	11809	-3486	799888	1107029
17	Government services of R-level	0	126213	940863	0	0	0	0	0	0	0	0	1067076	1067076
18	Clerical business	0	0	0	0	0	0	0	0	0	0	0	0	4275579
19	Water supply	161	100090	0	0	0	161	0	58	5	784	-692	100568	235299
20	Residential building	0	0	0	0	4265057	0	274260	0	0	0	0	4539317	4539317
21	Passenger transportation	315	1765641	0	0	0	28993	0	189898	76	94001	-47277	2031648	3335960
22	Freight transportation	11217	164178	0	0	0	60779	0	9069	5369	166137	-10238	406511	2202933
23	Communication	158	259208	0	0	0	864	0	173645	29	45912	-24019	455797	1267118
24	Finance, insurance and real estate	1031	4774686	0	0	0	7436	0	2679	250	812141	-199446	5398777	10900837
25	Business services	1776	53961	0	0	0	3474	0	1252	117	341800	-188735	213644	5092747
26	Entertainment	413603	972791	0	0	0	1186	0	427	40	59185	-43183	1404048	1738154
27	Public works of P-level	0	0	0	0	0	1337478	0	1219583	0	0	0	2557061	2564632
28	Community services of P-level	1799	988442	175824	462258	0	1333	0	480	-5396	43077	-190520	1477298	1954400
29	Government services of P-level	0	75112	0	1044594	0	0	0	0	0	0	0	1119706	1119706
30	Retail	151972	3573885	0	0	0	209044	0	16114	117	53105	-84911	3919326	5120381
31	Personal services	1491952	3043762	0	0	0	3023	0	1089	102	274654	-477623	4336958	4431578
32	Public works of C-level	0	0	0	0	0	24294	0	620696	0	0	0	644991	663514
33	Community services of C-level	53130	2586394	212059	688919	0	2459	0	886	83	11217	-41701	3513445	3604560
34	Government services of C-level	0	55699	0	774616	0	0	0	0	0	0	0	830315	830315
35	Sewage and waste management	31	51341	0	174247	0	221	0	80	7	964	-902	225988	324272
36	Intermediate inputs	2759708	31479276	1433427	3666169	4265057	9459889	274260	4685414	69332	26641459	-24951325	59782665	132986388

Table A.2. The regional input-output table (1980; Part 1).

		1 Agriculture, forestry and fisheries	2 Mining	3 Food and beverages	4 Textile	5 Wooden and paper products	6 Printing and publishing	7 Chemical products	8 Metal products	9 Machinery	10 Other manufacturing	11 Electricity and gas	12 Non-residential building
1	Agriculture, forestry and fisheries	457709	387	2631418	152546	481163	880	25170	8896	12847	112941	1743	3352
2	Mining	769	3381	1914	508	9202	646	5116883	376893	10108	355613	763373	34879
3	Food and beverages	417340	501	1287130	2326	13439	2180	110189	17356	30216	8109	1881	4288
4	Textile	27199	1172	20416	822076	31807	28275	26880	33266	103102	136336	5783	44214
5	Wooden and paper products	16494	1116	128097	6250	1642672	733166	193986	46872	208542	269218	12204	380026
6	Printing and publishing	5946	1184	30547	11313	224704	596711	30493	26154	115412	26377	6946	7235
7	Chemical products	450426	86998	253064	215026	221484	157746	3916295	916803	607073	1268876	817160	133626
8	Metal products	31508	7201	197323	27888	125993	28511	148157	7788791	4824478	191712	144389	1203257
9	Machinery	33940	3610	40852	7094	23789	9438	47413	97160	10086575	93582	30706	285844
10	Other manufacturing	51014	2435	197799	38445	69772	46698	253355	150119	1655935	1225012	79603	679208
11	Electricity and gas	23898	13115	104150	31637	120370	42555	283864	595470	395801	219070	52077	47164
12	Non-residential building	20857	2170	27377	7303	11045	9334	44600	53662	85482	23568	55501	9598
13	Far-flung transportation	25622	3584	97031	13878	36763	35730	90479	113527	153646	74912	26512	32774
14	Wholesale	73965	21789	467084	155305	254400	175744	300232	502556	1355354	418856	83391	399138
15	Public works of R-level	414	40	452	136	173	174	813	917	1435	401	1170	153
16	Community services of R-level	1266	442	14340	2355	4813	1927	114266	43621	370068	19615	10101	5758
17	Government services of R-level	206	26	447	121	242	184	728	776	1597	382	201	319
18	Clerical business	4035	34030	213743	76930	169495	486948	423953	447691	1663118	324950	272845	324291
19	Water supply	555	315	18898	1693	8761	632	26906	12882	23490	7393	2854	5291
20	Residential building	0	0	0	0	0	0	0	0	0	0	0	0
21	Passenger transportation	3418	8570	12219	6228	9704	9035	28653	26045	81691	22878	5247	19077
22	Freight transportation	40701	5376	100617	15053	37173	22050	94063	82108	199336	132689	23941	89343
23	Communication	11198	2082	22343	9665	21218	14294	85135	54679	187861	38706	6911	27147
24	Finance, insurance and real estate	89289	27833	128050	92241	124919	72826	474110	376772	635179	193695	245150	134804
25	Business services	120085	47472	436585	120801	162328	184502	492112	450458	1362039	371422	220715	297270
26	Entertainment	679	136	2773	424	1297	6576	2939	4802	8170	2141	426	1084
27	Public works of P-level	97	9	106	32	41	41	191	216	338	94	275	36
28	Community services of P-level	3536	1555	128370	10455	10255	8235	42923	63601	162683	74251	15786	30053
29	Government services of P-level	1046	133	2269	614	1228	936	3697	3942	8111	1943	1021	1620
30	Retail	68375	17247	39481	20703	31723	16420	36596	61466	155092	82319	11150	127960
31	Personal services	1719	344	7019	1074	3283	1350	7438	12154	20768	5418	1083	2745
32	Public works of C-level	286	28	- 312	94	120	120	562	633	991	277	808	106
33	Community services of C-level	1335	268	5435	834	2553	1057	5784	9421	16022	4200	853	2140
34	Government services of C-level	827	105	1793	485	971	740	2923	3116	6412	1536	807	1280
35	Sewage and waste management	574	492	4054	3041	5385	4573	28977	8917	36528	6844	17215	6335
36	Intermediate inputs	1996350	295144	6623508	1854571	3862285	2702237	12460765	12395842	24585498	5715536	2921828	4341413
37	Scrap metal	214	27	464	126	251	192	3126	396864	-224837	-2453	-104	-3318
38	Consumption expenditures outside households	27694	19445	171901	44279	81858	123297	287813	197690	578713	151358	46593	169946
39	Compensation of employees	335736	59534	774374	476423	695295	701251	604084	1543763	4570176	1233311	218817	1044007
40	Operating surplus	1531734	107806	733975	73618	262902	258301	594427	1116994	2335390	403675	516501	928609
41	Depreciation of fixed capital	467395	65196	276878	88456	173899	86438	578221	665351	1324485	453386	391499	223196
42	Indirect taxes	128036	13534	1162676	31563	63193	47168	942741	178590	781020	174340	178170	73382
43	(Less) Current subsidies	-112864	-3804	-255058	-1252	-2482	-1890	-7463	-7957	-24855	-3980	-2173	-3269
44	Total gross value added	2377944	261738	2865310	713212	1274914	1214756	3002949	4092295	9340092	2409638	1349303	2432553
45	Production	4374294	556882	9488818	2567783	5137200	3916992	15463714	16488137	33925591	8125172	4271131	6773967

Table A.2. The regional input-output table (1980; Part 2).

		13 Far-flung transportation	14 Wholesale	15 Public works of R-level	16 Community services of R-level	17 Government services of R-level	18 Clerical business	19 Water supply	20 Residential building	21 Passenger transportation	22 Freight transportation	23 Communication	24 Finance, insurance and real estate
1	Agriculture, forestry and fisheries	3004	2382	4565	3824	1021	0	347	3477	3145	1054	3132	8009
2	Mining	9232	2039	53451	2601	49	0	109	43831	11344	429	3375	3691
3	Food and beverages	3641	7973	887	3213	1497	0	785	3478	2715	2436	3855	18713
4	Textile	21823	41122	1293	6506	10089	0	1220	43609	10951	7002	10398	27134
5	Wooden and paper products	17082	90087	13156	34834	6980	0	1597	1091414	10769	4157	13772	45024
6	Printing and publishing	10264	55371	1840	166328	22716	0	1882	6394	8267	6136	39541	142231
7	Chemical products	368300	189009	49179	53643	50344	0	11510	111686	132257	196563	28281	90431
8	Metal products	85204	84920	79223	13610	2897	0	3370	759326	97907	10435	73477	78051
9	Machinery	204462	60220	15911	14063	173911	0	3236	144443	86806	11101	17224	75353
10	Other manufacturing	47202	26877	97923	46787	44669	0	3715	555809	53074	4626	21118	76878
11	Electricity and gas	90204	107528	11027	105583	22443	0	60444	38721	95499	26898	29877	77401
12	Non-residential building	28141	70704	1599	44678	4454	0	24461	9371	35504	7381	7938	882705
13	Far-flung transportation	750346	109566	5468	36069	23809	0	847	33800	14629	23203	25443	35208
14	Wholesale	51418	374616	42910	44070	21484	0	5055	428451	59076	47436	32864	101982
15	Public works of R-level	569	1448	21	918	95	0	514	148	726	125	116	18689
16	Community services of R-level	13859	3890	757	1103	2	0	279	5457	7733	1045	25405	6434
17	Government services of R-level	169	600	0	157	0	0	22	0	139	102	110	911
18	Clerical business	531556	2355668	0	0	0	0	0	0	0	0	0	0
19	Water supply	6409	4337	778	22811	1894	0	67	5451	5664	5262	4033	5785
20	Residential building	0	0	0	0	0	0	0	0	0	0	0	0
21	Passenger transportation	54380	150111	2944	22795	24703	0	599	16522	25219	28418	8429	35855
22	Freight transportation	68188	20075	12529	7728	3539	0	1024	90619	31965	27040	26584	16812
23	Communication	20377	284329	4773	35659	18722	0	2052	19364	10800	18902	34061	184286
24	Finance, insurance and real estate	289697	1425357	18504	106529	13212	0	19956	128129	142101	74992	72507	714277
25	Business services	114386	551081	64856	183229	131283	0	24440	231915	200121	177081	72063	754731
26	Entertainment	711	1408	278	889	340	0	228	1089	736	680	1124	5123
27	Public works of P-level	134	341	5	215	22	0	121	35	171	29	27	4397
28	Community services of P-level	21960	34199	4144	8354	1805	0	1217	25092	10134	7988	25124	67310
29	Government services of P-level	857	3047	0	797	0	0	111	0	707	518	557	4627
30	Retail	18967	140791	7104	45867	13333	0	2366	78177	22045	43522	14076	66244
31	Personal services	5007	3584	703	2261	8	0	582	2757	1899	1739	2955	12965
32	Public works of C-level	393	1000	14	632	66	0	355	102	501	86	80	12910
33	Community services of C-level	44157	3409	544	1723	11	0	451	2135	2568	1346	2198	10086
34	Government services of C-level	678	2409	0	630	0	0	88	0	559	409	441	3658
35	Sewage and waste management	28550	11830	636	6228	4075	0	233	6564	13466	3483	3530	8357
36	Intermediate inputs	2911325	6221305	497023	1024334	609473	0	173281	3887365	1099219	741626	603719	3598246
37	Scrap metal	-1084	623	-189	163	0	0	23	-403	-1437	106	22	946
38	Consumption expenditures outside households	76186	504803	19537	20881	57010	0	7960	165119	83324	63375	29138	189545
39	Compensation of employees	594410	2951241	293101	2110510	928990	7329252	179744	1465042	1330019	1038349	973176	3032806
40	Operating surplus	-96649	2173732	69308	8251	0	0	30185	901786	239858	189504	170288	8159403
41	Depreciation of fixed capital	233553	531467	52042	198105	59504	0	85048	188988	254981	112396	524357	3811296
42	Indirect taxes	73472	451993	7523	4016	10360	0	17912	77028	52049	43255	32283	866663
43	(Less) Current subsidies	-206350	-89447	-1344	-31955	0	0	-30409	0	-100712	-23371	-1399	-303644
44	Total gross value added	673538	6524411	439978	2309971	1055864	7329252	290463	2797560	1858083	1423612	1727865	15757015
45	Production	3584863	12745717	937000	3334305	1665337	7329252	463744	6684925	2957302	2165238	2331584	19353261

Table A.2. The regional input-output table (1980; Part 3).

		25 Business services	26 Entertainment	27 Public works of P-level	28 Community services of P-level	29 Government services of P-level	30 Retail	31 Personal services	32 Public works of C-level	33 Community services of C-level	34 Government services of C-level	35 Sewage and waste management	36 Intermediate demands
1	Agriculture, forestry and fisheries	4471	13795	11951	528392	11	3026	408389	6710	48552	9	242	4958559
2	Mining	2032	604	174264	932	31	1594	1481	72710	2035	24	176	7060203
3	Food and beverages	10431	4763	2468	23079	24	8037	989304	1238	84173	19	582	3048264
4	Textile	47516	8625	4976	19811	7946	32579	32091	1597	21421	6282	3450	1647967
5	Wooden and paper products	903671	17419	49387	40514	7774	93297	60008	16732	68311	6146	5924	6238675
6	Printing and publishing	653977	35978	6695	89786	31766	31575	21817	2464	95793	25113	2855	2543811
7	Chemical products	217364	114728	132381	219594	24852	343550	170484	58364	860896	19647	60955	12558598
8	Metal products	60827	12358	436022	16302	1950	49946	50610	108392	38169	1542	3598	16787345
9	Machinery	1265112	13920	71660	16383	3439	35945	13883	26307	47630	2719	2998	13066728
10	Other manufacturing	368993	29218	460128	28643	9085	56543	83248	144237	41203	7182	6090	6664641
11	Electricity and gas	68840	64435	32788	51920	25432	134718	260186	15447	110502	20105	33815	3412983
12	Non-residential building	35894	31237	5767	23521	35202	64061	23394	2232	41149	27829	6956	1764675
13	Far-flung transportation	61251	16824	22928	18931	19564	52707	34702	7299	32632	15466	4380	2049627
14	Wholesale	457581	46966	185263	66885	11683	113567	326749	60271	202531	9236	14843	6932770
15	Public works of R-level	630	628	86	459	755	1281	481	29	602	597	142	35534
16	Community services of R-level	19070	1064	3050	1300	8	2766	755	1020	2076	7	198	666050
17	Government services of R-level	498	140	0	146	0	418	354	0	273	0	39	9304
18	Clerical business	0	0	0	0	0	0	0	0	0	0	0	7329252
19	Water supply	6055	7020	2908	13170	2057	3212	46896	890	25657	1626	1247	282877
20	Residential building	0	0	0	0	0	0	0	0	0	0	0	0
21	Passenger transportation	17455	18897	12365	12453	32036	57832	28494	4128	16950	25326	3402	833877
22	Freight transportation	54358	17178	49802	12223	2308	28059	79141	16627	17359	1825	13163	1440595
23	Communication	82902	51874	18966	23807	16276	124060	44983	6493	37883	12867	6877	1541534
24	Finance, insurance and real estate	384540	127440	77919	55160	9844	763008	272729	25738	111837	7782	16409	7452536
25	Business services	596833	183865	259627	138206	89516	778981	191117	91775	228580	70767	54458	9454702
26	Entertainment	535345	100088	773	1110	244	1910	5625	388	1779	193	154	691665
27	Public works of P-level	148	148	20	108	178	301	113	7	189	140	33	8359
28	Community services of P-level	60076	60244	17642	5833	8	25965	155403	5832	31883	6	2617	1124541
29	Government services of P-level	2529	711	0	739	0	2121	1799	0	1388	0	196	47265
30	Retail	215140	42969	19562	45750	12591	120188	311365	8511	106304	9954	12052	2025409
31	Personal services	7248	2675	1957	4920	23	5712	1979	982	24947	18	387	149680
32	Public works of C-level	435	434	59	317	521	885	332	20	554	412	98	24545
33	Community services of C-level	5650	1680	1518	2127	19	4079	897	760	4778	15	297	140368
34	Government services of C-level	1999	582	0	584	0	1677	1422	0	1098	0	155	37365
35	Sewage and waste management	4269	12918	4381	5478	42562	11111	36356	604	20714	33648	1000	383128
36	Intermediate inputs	6153141	1041205	2067290	1488584	387701	2954710	3636588	688004	2330027	306500	259789	122433430
37	Scrap metal	517	145	-780	151	0	434	370	-217	284	0	40	170267
38	Consumption expenditures outside households	233086	78674	75595	43559	39354	209777	162650	27060	81661	31112	14454	4114446
39	Compensation of employees	2843293	625470	1053647	1368339	1211656	3356820	2149841	409671	2613653	957884	415295	51489181
40	Operating surplus	953743	664292	246645	93114	0	1747224	953441	93543	443341	0	42641	25947580
41	Depreciation of fixed capital	272663	191828	224261	107996	43818	349848	318088	78590	269593	34640	81131	12819693
42	Indirect taxes	133155	373877	36066	20994	0	257338	305646	10280	71128	0	8136	6627587
43	(Less) Current subsidies	-11852	-3027	-7518	-30530	0	-4476	-3631	-2708	-2803	0	-396	-1282622
44	Total gross value added	4424606	1931260	1627916	1603623	1294827	5916965	3886405	616219	3477058	1023637	561301	99886132
45	Production	10577746	2972465	3695205	3092206	1682528	8871675	7522992	1304223	5807085	1330137	821090	222319562

Table A.2. The regional input-output table (1980; Part 4).

		37 Consumption expenditures outside households	38 Household consumption expenditures	39 Central government consumption expenditures	40 Local government consumption expenditures	41 Private housing investment	42 Private capital formation except housing	43 Government housing investment	44 Government capital formation except housing	45 Net increase in stocks	46 Export	47 (Less) Import	48 Total final demand	49 Production
1	Agriculture, forestry and fisheries	43886	1645917	0	0	0	39527	0	0	-96167	601953	-2819380	-584265	4374294
2	Mining	0	7433	0	0	0	0	0	0	83952	23832	-6618539	-6503322	556882
3	Food and beverages	229601	7272636	0	0	0	0	0	0	-2584	2029900	-3088998	6440554	9488818
4	Textile	91469	2003407	0	0	0	22529	0	4025	5393	605581	-2012588	919816	2587783
5	Wooden and paper products	89691	130957	0	0	0	219558	0	47545	63177	968238	-2620640	-1101475	5137200
6	Printing and publishing	18391	460918	0	0	0	0	0	0	8334	1144472	-256932	1373182	3916992
7	Chemical products	76867	1642879	0	0	0	0	0	0	898	5106026	-3921555	2905116	15483714
8	Metal products	53211	297595	0	0	0	195588	0	37978	-22817	5173231	-8034194	-299208	16488137
9	Machinery	59058	1813825	0	0	0	6364899	0	1343447	666537	18352578	-7741281	20858862	33925591
10	Other manufacturing	122384	1120181	0	0	0	175994	0	37283	15904	2728880	-2740074	1460531	8125172
11	Electricity and gas	1340	1011411	0	0	0	613387	0	17829	-1287	148013	-932544	858148	4271131
12	Non-residential building	0	0	0	0	0	3856876	0	1164928	-2041	9571	-20042	5009291	6773967
13	Far-flung transportation	4838	889594	-14760	46289	0	72723	0	351737	3255	1490496	-1308935	1535236	3584863
14	Wholesale	127882	2686607	0	0	0	1030080	0	183052	42243	3585156	-1842054	5812947	12745717
15	Public works of R-level	0	0	0	0	0	10904	0	890562	0	0	0	901466	937000
16	Community services of R-level	0	731009	232081	1808800	0	0	0	0	-1005	87236	-9865	2848256	3334305
17	Government services of R-level	0	8405	1647628	0	0	0	0	0	0	0	0	1656033	1665337
18	Clerical business	0	0	0	0	0	0	0	0	0	0	0	0	7329252
19	Water supply	254	181562	0	0	0	0	0	0	-140	817	-1626	180867	463744
20	Residential building	0	0	0	0	6365952	0	318973	0	0	0	0	6684925	6684925
21	Passenger transportation	28553	1519752	0	0	0	56387	0	431319	-891	209844	-119540	2123425	2957302
22	Freight transportation	17608	366381	0	0	0	68727	0	12880	5166	277947	-22074	724644	2165238
23	Communication	81	510776	0	0	0	0	0	221672	-703	88210	-29987	790050	2331584
24	Finance, insurance and real estate	0	11435506	0	0	0	0	0	0	-5832	700872	-229819	11900726	19353261
25	Business services	1358	656192	0	0	0	0	0	0	-3188	608273	-139591	1123044	10577746
26	Entertainment	859248	1592847	0	0	0	0	0	0	-896	93196	-63594	2280800	2972465
27	Public works of P-level	0	0	0	0	0	1676036	0	2010811	0	0	0	3686846	3695205
28	Community services of P-level	1624	1577913	282380	452767	0	0	0	0	632	98097	-445747	1967665	3092208
29	Government services of P-level	0	53222	0	1582042	0	0	0	0	0	0	0	1635264	1682528
30	Retail	254406	6067741	0	0	0	540059	0	27351	-2673	182565	-223183	6846266	8871675
31	Personal services	2175657	5913068	0	0	0	0	0	0	-2267	718426	-1431572	7373312	7522992
32	Public works of C-level	0	0	0	0	0	20005	0	1259673	0	0	0	1279678	1304223
33	Community services of C-level	73428	4774324	55469	828725	0	0	0	0	-1750	8610	-72088	5666718	5807085
34	Government services of C-level	0	42075	0	1250696	0	0	0	0	0	0	0	1292771	1330137
35	Sewage and waste management	43	151775	0	287661	0	0	0	0	-247	1161	-2429	437962	821090
36	Intermediate inputs	4126878	56565687	2202798	6056979	6365952	14961260	318973	8042102	751201	45243178	-44748876	99886132	222319562

Table A.3. The interzonal time distances by car $TF^{cc'}$ (minutes).

	100	200	300	401	402	403	404	405	406	407	408	409	410	501	502	503	504	505	506	507	508	509	510	511	512
100	40	134	186	109	147	119	121	151	92	130	150	178	199	118	87	112	111	102	145	208	94	139	140	220	303
200	134	34	106	70	64	85	129	91	67	36	49	98	170	140	117	156	176	158	166	230	211	230	162	242	324
300	186	106	35	104	81	90	82	47	111	87	64	8	86	150	127	166	186	168	176	239	248	240	172	252	334
401	109	70	104	11	42	15	66	69	32	39	59	96	140	77	54	93	113	95	103	167	175	167	99	179	261
402	147	64	81	42	17	53	67	38	55	44	50	73	119	120	96	135	155	137	146	209	218	210	141	221	304
403	119	85	90	15	53	15	61	55	47	54	74	82	126	83	60	99	119	101	109	173	181	173	105	185	267
404	171	129	87	66	67	61	18	47	87	98	101	74	84	85	59	101	121	103	111	175	183	175	107	187	269
405	151	91	47	69	38	55	47	18	88	71	57	39	84	115	97	131	151	133	142	205	213	206	137	217	300
406	92	67	111	32	55	47	82	88	19	38	57	103	160	90	67	105	176	108	116	179	170	180	112	192	274
407	130	36	87	39	44	54	98	71	38	19	33	79	151	109	85	125	145	127	135	198	207	199	131	211	293
408	150	49	64	59	50	74	101	57	57	33	15	56	132	129	105	145	164	147	155	218	227	219	151	230	313
409	178	98	8	96	73	82	74	39	103	79	56	21	78	147	119	158	178	160	168	231	240	232	164	244	326
410	199	170	86	140	119	126	84	84	160	151	132	78	28	164	137	179	199	181	190	253	262	254	185	265	348
501	118	140	150	77	120	83	85	115	90	109	129	142	164	17	32	74	60	43	31	95	125	102	34	114	189
502	87	117	127	54	96	60	59	92	67	85	105	119	137	32	17	51	67	49	58	121	132	122	53	133	216
503	112	156	166	93	135	99	101	131	105	125	145	158	179	74	51	31	94	72	100	164	127	164	96	176	258
504	111	176	186	113	155	119	121	151	126	145	164	178	199	60	67	94	21	27	92	155	65	75	68	145	250
505	107	158	168	95	137	101	103	133	108	127	147	160	181	43	49	72	27	15	74	137	97	94	61	141	232
506	145	166	176	103	146	109	111	142	116	135	155	168	190	31	58	100	92	74	23	80	156	125	57	97	175
507	208	230	239	167	209	173	175	205	179	198	218	231	253	95	121	164	155	137	80	36	219	189	120	139	103
508	94	211	248	175	218	181	183	213	170	207	227	240	262	125	132	127	65	92	156	219	29	71	121	194	314
509	139	230	240	167	210	173	175	206	180	199	219	232	254	102	122	164	75	94	125	189	71	23	68	127	261
510	140	162	172	99	141	105	107	137	112	131	151	164	185	34	53	96	68	61	57	120	121	68	24	80	214
511	220	242	252	179	221	185	187	217	192	211	230	244	265	114	133	176	145	141	97	139	194	127	80	38	134
512	303	324	334	261	304	267	269	300	274	293	313	326	348	189	216	258	250	232	175	103	314	261	214	134	39
601	97	108	117	45	87	57	39	82	48	76	96	109	118	58	34	77	93	76	84	147	158	148	80	159	242
602	97	105	110	42	85	51	32	75	55	74	94	102	111	65	41	81	100	83	91	154	163	155	87	166	249
603	96	106	122	44	86	56	44	87	42	75	94	114	123	57	34	76	93	75	84	147	157	147	79	159	242
604	113	123	123	60	102	72	46	89	65	91	111	115	125	74	49	93	110	92	101	164	174	164	96	176	259
605	104	114	106	51	91	57	28	71	62	82	102	98	107	66	34	85	102	84	92	155	166	156	88	168	250
606	103	111	101	48	80	44	24	67	64	80	99	93	103	67	43	83	103	85	93	156	165	157	89	169	251
607	93	101	92	38	70	34	33	58	54	70	90	84	112	58	34	73	93	75	84	147	156	148	79	159	242
608	80	92	109	29	72	41	44	74	38	61	81	101	122	55	32	71	91	73	81	145	153	145	77	157	239
609	119	127	113	59	90	44	36	79	80	96	116	105	115	83	53	99	119	101	109	173	181	173	105	185	267
610	139	137	117	67	95	52	48	83	98	106	125	109	113	90	58	109	125	108	116	179	190	180	112	191	274
611	130	119	101	49	77	34	47	66	81	88	108	93	111	94	70	110	130	112	120	183	192	184	116	196	278
612	141	143	127	73	104	63	59	92	102	112	131	119	123	94	63	113	130	112	120	184	194	184	116	196	278
613	127	146	130	76	106	63	60	95	104	114	134	122	130	72	41	91	108	90	98	162	172	162	94	174	256
614	119	127	101	64	87	54	28	66	80	95	115	93	92	83	57	99	119	101	109	172	181	173	105	185	267
701	134	150	145	87	129	95	68	110	95	119	139	137	146	79	48	98	115	97	106	169	179	169	101	181	264
702	131	141	141	78	120	90	64	106	87	110	130	133	142	88	56	107	124	106	114	177	188	178	110	190	272
703	135	156	151	93	136	101	74	117	104	125	145	143	152	80	49	99	116	98	107	170	180	170	102	182	265
704	112	142	140	79	121	85	63	105	92	111	130	132	141	57	25	76	92	75	83	146	157	147	79	158	241
705	121	131	132	68	111	80	55	97	74	100	120	124	133	83	52	102	119	101	109	173	183	173	105	185	267
706	120	130	121	67	101	60	44	86	78	99	119	113	122	68	37	87	104	86	95	158	168	158	90	170	253
707	157	178	173	115	157	123	96	138	126	147	167	165	174	102	70	121	138	120	128	191	202	192	124	204	286
708	133	164	161	101	143	107	84	127	113	132	152	153	163	78	47	97	114	96	105	168	178	168	100	180	263
709	114	144	147	81	123	87	70	113	94	113	133	139	149	59	27	78	95	77	85	148	159	149	81	161	243
710	120	150	148	87	130	93	71	113	100	119	139	140	149	65	34	84	101	83	91	154	165	155	87	167	249
711	146	177	174	114	156	120	97	140	126	145	165	166	176	91	60	110	127	109	118	181	191	181	113	193	276
712	137	151	136	81	113	72	68	101	110	120	140	128	132	82	50	101	118	100	108	171	182	172	104	184	266

	601	602	603	604	605	606	607	608	609	610	611	612	613	614	701	702	703	704	705	706	707	708	709	710	711	712	TP
100	97	97	96	113	104	103	93	80	119	139	130	141	127	119	134	131	135	112	121	120	157	133	114	120	146	137	40
200	108	105	106	123	114	111	101	92	127	137	119	143	146	127	150	141	156	142	131	130	178	164	144	150	177	151	106
300	117	110	122	123	106	101	92	109	113	117	101	127	130	101	165	141	151	140	132	121	173	161	147	148	174	136	117
401	45	42	44	60	51	48	38	29	59	67	49	73	76	64	87	78	93	79	68	67	115	101	81	87	114	81	44
402	87	85	86	102	91	80	70	72	90	95	77	104	106	87	129	120	136	121	111	101	157	143	123	130	156	113	86
403	57	51	56	72	57	44	34	41	44	52	34	63	63	54	95	90	101	85	80	60	123	107	87	93	120	72	56
404	39	32	44	46	28	24	33	44	36	48	47	59	60	28	68	64	74	63	55	44	96	84	70	71	97	68	39
405	82	75	87	89	71	67	58	74	79	83	66	97	95	66	110	106	117	105	97	86	138	127	113	113	140	101	82
406	48	55	42	65	62	64	54	38	80	98	81	102	104	80	95	87	104	92	74	78	126	113	94	100	126	110	42
407	76	74	75	91	82	80	70	61	96	106	88	112	114	95	119	110	125	111	100	99	147	132	113	119	145	120	75
408	96	94	94	111	102	99	90	81	116	125	108	131	134	115	139	130	145	130	120	119	167	152	133	139	165	140	94
409	109	102	114	115	98	93	84	101	105	109	93	119	122	93	137	133	143	132	124	113	165	153	139	140	166	128	109
410	118	111	123	125	107	103	112	122	115	113	111	123	130	92	146	142	152	141	133	122	174	163	149	149	176	132	118
501	58	65	57	74	66	67	58	55	83	90	94	94	72	83	79	88	80	57	83	68	102	78	59	65	91	82	17
502	34	41	34	49	34	43	34	32	53	58	70	63	41	57	48	56	49	75	52	37	70	47	27	34	60	50	17
503	77	81	76	93	85	83	73	71	99	109	110	113	91	99	98	107	99	76	102	87	121	97	78	84	110	101	51
504	93	100	93	110	102	103	93	91	119	125	130	130	108	119	115	124	116	92	119	104	138	114	95	101	127	118	60
505	76	83	75	92	84	85	75	73	101	108	112	117	90	101	97	106	98	75	101	86	120	96	77	83	109	100	43
506	84	91	84	101	92	93	84	81	109	116	120	120	98	109	106	114	107	83	109	95	128	105	85	91	118	108	23
507	147	154	147	164	155	156	147	145	173	179	183	184	162	172	169	177	170	146	173	158	191	168	148	154	181	171	36
508	158	163	157	174	166	165	156	153	181	190	192	194	172	181	179	188	180	157	183	168	202	178	159	165	191	182	94
509	148	155	147	164	156	157	148	145	173	180	184	184	162	173	169	178	170	147	173	158	192	168	149	155	181	172	102
510	80	87	79	96	88	89	79	77	105	112	116	116	94	105	101	110	102	79	105	90	124	100	81	87	113	104	34
511	159	166	159	176	168	169	159	157	185	191	196	196	174	185	181	190	187	158	185	170	204	180	161	167	193	184	97
512	242	249	242	259	250	251	242	239	267	274	278	278	256	267	264	272	265	241	267	253	286	263	243	249	276	266	103
601	6	16	10	22	19	28	31	18	38	58	56	61	62	37	52	44	62	50	32	36	84	72	58	58	85	70	6
602	16	7	20	33	19	14	17	17	30	51	49	53	54	30	55	51	61	49	41	35	83	71	57	58	84	62	16
603	10	20	6	27	24	32	31	16	43	63	61	66	67	42	57	49	67	55	36	41	88	76	61	63	89	75	6
604	22	33	27	8	22	34	43	33	45	65	63	66	63	44	43	34	59	57	18	38	81	74	60	61	87	75	8
605	19	19	24	22	7	17	26	24	27	47	45	47	46	26	43	39	50	38	30	19	71	60	46	46	73	56	19
606	28	14	32	34	17	6	15	26	20	43	38	47	48	22	56	52	62	51	43	32	84	72	58	59	85	56	28
607	31	17	31	43	26	15	9	16	31	50	36	47	50	31	65	61	71	59	52	41	93	81	61	68	94	56	31
608	18	17	16	33	24	26	16	9	42	62	53	64	66	42	60	51	67	55	42	41	88	76	59	63	89	77	16
609	38	30	43	45	27	20	31	42	10	36	30	30	31	34	64	60	71	56	53	24	97	78	60	65	91	39	38
610	58	51	63	65	47	43	50	62	36	8	22	24	18	26	86	77	92	71	71	38	114	92	58	71	105	36	58
611	56	49	61	63	45	38	36	53	30	22	11	46	33	24	84	80	91	79	71	44	112	100	75	87	113	56	56
612	61	53	66	66	47	47	47	64	30	24	46	10	39	37	80	74	87	72	67	37	108	87	50	63	98	22	61
613	62	54	67	63	46	48	50	66	31	18	33	39	14	44	76	65	77	53	59	27	98	75	42	61	88	51	41
614	37	30	42	44	26	22	31	47	34	26	24	37	44	15	65	62	72	60	53	42	93	82	68	69	95	45	37
701	52	55	57	43	43	56	65	60	64	86	84	80	76	65	9	28	25	23	33	53	51	61	56	60	86	77	9
702	44	51	49	34	39	52	61	51	60	77	80	74	65	62	28	14	41	34	22	41	62	67	65	68	95	82	22
703	62	61	67	59	50	62	71	67	71	92	91	87	77	72	25	41	9	27	51	59	32	49	57	61	87	78	9
704	50	49	55	52	38	51	59	55	56	71	79	72	53	60	23	34	27	13	44	44	48	50	34	37	63	54	23
705	32	41	36	18	30	43	52	42	53	71	71	67	59	53	33	22	51	44	9	34	72	77	63	84	90	75	9
706	36	35	41	38	19	32	41	41	24	38	44	37	27	42	53	41	59	44	34	10	80	66	38	53	79	45	34
707	84	83	88	81	71	84	93	88	97	114	112	108	98	93	51	62	32	48	72	80	17	68	79	82	109	99	37
708	72	71	76	74	60	72	81	76	78	92	100	87	75	82	61	67	49	50	77	66	68	15	38	24	51	53	47
709	58	57	61	60	46	58	61	59	60	58	75	50	42	68	56	65	57	34	63	38	79	38	14	22	57	52	27
710	58	58	63	61	46	59	68	63	65	71	87	63	61	69	60	68	61	37	84	53	82	24	22	10	35	39	34
711	85	84	89	87	73	85	94	89	91	105	113	98	88	95	86	95	87	63	90	79	109	51	35	35	13	29	60
712	70	62	75	75	56	56	56	72	39	36	56	22	51	45	77	82	78	54	75	45	99	53	52	39	29	13	50

Note: These time distances apply to the freight transportation.
They are calculated by assuming the following overall speeds; 80 km/hr on the national expressways, 55 km/hr on the urban expressways, and 30 km/hr on the remaining routes.

Table A.4. The interzonal time distances by rail $TM^{CC'}$ (minutes).

	100	200	300	401	402	403	404	405	406	407	408	409	410	501	502	503	504	505	506	507	508	509	510	511	512
100	47	123	175	154	176	170	208	203	134	156	177	214	258	165	138	91	141	165	180	213	191	232	199	225	268
200	123	38	129	89	105	135	159	149	111	60	91	143	186	182	156	135	185	181	199	232	235	265	232	244	287
300	175	129	39	104	82	150	129	117	139	120	89	44	119	198	178	167	213	203	214	247	267	281	248	259	302
401	154	89	104	12	22	36	76	76	25	29	60	60	120	86	68	58	104	94	110	143	158	169	136	155	198
402	176	105	82	22	18	68	92	82	57	45	57	38	98	116	96	85	131	121	132	165	185	199	166	177	220
403	170	135	150	36	68	18	63	33	37	75	106	106	113	98	80	70	118	108	112	145	170	181	148	157	200
404	208	159	129	76	92	63	19	67	77	99	115	116	43	136	118	110	156	146	150	183	208	219	186	195	238
405	203	149	117	76	82	33	67	24	77	89	93	94	80	131	113	110	151	141	145	178	203	214	181	190	233
406	134	111	139	25	57	37	77	77	14	41	62	95	127	61	43	33	91	81	85	118	143	144	111	130	173
407	156	60	170	29	45	75	99	89	41	13	21	76	116	112	86	65	115	111	131	164	165	195	162	176	219
408	177	91	89	60	57	106	115	93	62	21	14	45	85	133	107	86	136	132	152	185	186	216	183	197	240
409	214	143	44	60	38	106	116	94	95	76	45	22	86	154	134	123	169	159	170	203	223	237	204	215	258
410	258	186	119	120	98	113	43	80	127	116	85	86	27	186	168	160	206	196	200	233	258	269	236	245	288
501	165	182	198	86	116	98	136	131	61	112	133	154	186	11	18	64	32	38	14	47	72	73	40	59	102
502	138	156	178	68	96	80	118	113	43	86	107	134	168	18	10	37	35	25	32	65	89	101	68	77	120
503	91	135	167	58	85	70	110	110	33	65	86	123	160	64	37	15	50	74	79	112	100	141	108	124	167
504	141	185	213	104	131	118	156	151	91	115	136	169	206	32	35	50	12	10	56	89	40	81	48	101	144
505	165	181	203	94	121	108	146	141	81	111	132	159	196	38	25	74	10	10	62	95	64	77	44	107	150
506	180	199	214	110	132	112	150	145	85	131	152	170	200	14	32	79	56	62	14	33	96	97	64	83	88
507	213	232	247	143	165	145	183	178	118	164	185	203	233	47	65	112	89	95	33	23	129	130	97	116	55
508	191	235	267	158	185	170	208	203	143	165	186	223	258	72	89	100	40	64	96	129	22	66	88	141	184
509	232	265	281	169	199	181	219	214	144	195	216	237	269	73	101	141	81	77	97	130	66	17	33	110	185
510	199	232	248	136	166	148	186	181	111	162	183	204	236	40	68	108	48	44	64	97	88	33	18	67	152
511	225	244	259	155	177	157	195	190	130	176	197	215	245	59	77	124	101	107	83	116	141	110	67	29	103
512	268	287	302	198	220	200	238	233	173	219	240	258	288	102	120	167	144	150	88	55	184	185	152	103	26
601	136	129	144	40	62	43	81	76	52	62	83	100	131	44	26	45	74	64	58	91	116	127	94	103	146
602	149	134	149	45	67	37	75	70	70	74	101	105	125	66	48	58	96	86	84	117	142	149	116	129	172
603	129	115	141	37	59	61	99	94	40	45	66	97	149	59	31	38	66	56	76	109	120	142	109	121	164
604	157	146	161	57	79	71	109	104	78	86	112	117	159	73	55	66	102	92	87	120	145	156	123	132	175
605	169	154	169	65	87	57	95	90	90	94	122	125	145	92	72	78	117	107	107	140	165	175	142	152	195
606	163	151	166	62	84	54	86	87	79	89	110	122	136	78	52	72	100	90	93	126	151	161	128	138	181
607	165	140	155	46	73	14	78	54	47	80	111	111	128	93	75	74	113	103	107	140	165	176	143	152	195
608	139	135	158	49	76	63	101	96	45	65	86	114	151	51	20	48	55	45	65	98	109	132	99	110	153
609	173	161	176	68	94	60	76	97	69	99	120	132	126	88	62	82	110	100	103	136	161	171	138	148	191
610	197	160	175	61	93	53	54	93	62	100	131	131	107	108	90	95	138	128	122	155	180	191	158	167	210
611	193	175	190	76	108	68	57	108	77	115	146	146	107	117	89	102	137	127	131	164	189	200	167	176	219
612	202	171	179	72	104	64	50	104	73	111	142	142	103	119	101	106	149	139	133	166	191	202	169	178	221
613	194	179	194	90	112	82	100	115	93	119	146	150	150	111	93	103	141	131	129	162	187	194	161	174	217
614	233	201	190	102	134	94	61	128	103	141	172	172	114	149	131	136	179	169	163	196	221	232	199	208	251
701	179	167	183	79	101	84	122	117	92	97	118	139	172	87	69	88	108	98	101	134	159	170	137	146	189
702	196	185	200	96	118	91	110	124	117	125	147	156	163	112	94	105	137	127	126	159	184	195	162	171	214
703	189	175	194	90	112	94	132	127	100	105	126	150	182	103	80	98	116	106	119	152	170	186	153	164	207
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705	178	167	182	78	100	89	112	122	99	107	130	138	162	91	73	87	120	110	105	138	163	174	141	150	193
706	176	162	177	73	95	65	84	98	77	102	123	133	134	94	76	85	124	114	112	145	170	177	144	157	200
707	220	206	225	121	143	175	163	158	131	136	157	181	213	132	111	129	147	137	146	179	201	215	182	191	234
708	211	200	215	111	133	115	148	148	128	135	156	171	201	117	99	120	146	136	131	164	189	200	167	176	219
709	208	194	209	105	127	97	109	130	119	134	155	165	162	126	108	117	156	146	144	177	202	209	176	189	232
710	222	208	223	119	141	111	123	144	133	148	169	179	176	140	122	131	170	160	158	191	216	223	190	203	246
711	241	230	245	141	163	144	156	177	158	165	186	201	209	147	129	150	176	166	161	194	219	230	197	206	249
712	221	189	204	90	122	82	78	122	91	129	160	160	131	137	119	124	167	157	151	184	209	220	187	196	239

	601	602	603	604	605	606	607	608	609	610	611	612	613	614	701	702	703	704	705	706	707	708	709	710	711	712
100	136	149	129	157	169	163	165	139	173	192	193	202	194	233	179	196	189	200	178	176	220	211	208	222	241	221
200	129	134	115	146	154	151	140	135	161	160	175	171	179	201	167	185	175	188	167	162	206	200	194	208	230	189
300	144	149	141	161	169	166	155	158	176	175	190	179	194	190	183	200	194	204	182	177	225	215	209	223	245	204
401	40	45	37	57	65	62	46	49	68	61	76	72	90	102	79	96	90	100	78	73	121	111	105	119	141	90
402	62	67	59	79	87	84	73	76	94	93	108	104	112	134	101	118	112	122	100	95	143	133	127	141	163	122
403	43	37	61	71	57	54	14	63	60	53	68	64	82	94	84	91	94	105	89	65	125	115	97	111	144	82
404	81	75	99	109	95	86	78	101	76	54	57	50	100	61	122	110	132	138	112	84	163	148	109	123	156	78
405	76	70	94	104	90	87	54	96	97	93	108	104	115	128	117	124	127	138	122	98	158	148	130	144	177	122
406	52	70	40	78	90	79	47	45	69	62	77	73	93	103	92	117	100	113	99	77	131	128	119	133	158	91
407	62	74	45	86	94	89	80	65	99	100	115	111	119	141	97	125	105	118	107	102	136	135	134	148	165	129
408	83	101	66	112	122	110	111	86	120	131	146	142	146	172	118	147	126	139	130	123	157	156	155	169	186	160
409	100	105	97	117	125	122	111	114	132	131	146	142	150	172	139	156	150	160	138	133	181	171	165	179	201	160
410	131	125	149	159	145	136	128	151	126	107	107	103	150	114	172	163	182	191	162	134	213	201	162	176	209	131
501	44	66	59	73	92	78	93	51	88	108	117	119	111	149	87	112	103	108	91	94	132	117	126	140	147	137
502	26	48	31	55	72	52	75	20	62	90	89	101	93	131	69	94	80	90	73	76	111	99	108	122	129	119
503	45	58	38	66	78	72	74	48	82	95	102	106	103	136	88	105	98	109	87	85	129	120	117	131	150	124
504	74	96	66	102	117	100	113	55	110	138	137	149	141	179	108	137	116	129	120	124	147	146	156	170	176	167
505	64	86	56	92	107	90	103	45	100	128	127	139	131	169	98	127	106	119	110	114	137	136	146	160	166	157
506	58	84	76	87	107	93	107	65	103	122	131	133	129	163	101	126	119	122	105	112	146	131	144	158	161	151
507	91	117	109	120	140	126	140	98	136	155	164	166	162	196	134	159	152	155	138	145	179	164	177	191	194	184
508	116	142	120	145	165	151	165	109	161	180	189	191	187	221	159	184	170	180	163	170	201	189	202	216	219	209
509	127	149	142	156	175	161	176	132	171	191	200	202	194	232	170	195	186	191	174	177	215	200	209	223	230	220
510	94	116	109	123	142	128	143	99	138	158	167	169	161	199	137	162	153	158	141	144	182	167	176	190	197	187
511	103	129	121	132	152	138	152	110	148	167	176	178	174	208	146	171	164	167	150	157	191	176	189	203	206	196
512	146	172	164	175	195	181	195	153	191	210	219	221	217	251	189	214	207	210	193	200	234	219	232	246	249	239
601	7	14	19	17	37	23	38	30	33	52	60	63	59	93	31	56	49	52	35	40	76	61	72	86	91	81
602	14	8	32	34	20	9	32	42	19	38	49	43	35	79	47	54	57	68	53	18	88	79	50	64	97	67
603	19	32	10	36	48	41	56	11	51	70	79	81	77	111	42	71	50	63	54	60	81	80	92	104	110	99
604	17	34	36	10	42	50	66	47	60	77	86	87	75	118	22	39	40	43	21	49	71	57	76	84	87	108
605	37	20	48	42	13	39	52	62	46	65	72	65	52	106	45	52	63	66	49	36	94	85	68	82	115	94
606	23	9	41	50	39	9	49	53	10	29	40	40	54	70	64	73	76	85	68	37	107	94	69	83	116	58
607	38	32	56	66	52	49	16	58	59	63	76	74	77	104	79	86	89	100	84	60	120	110	92	106	139	92
608	30	42	11	47	62	53	58	12	63	86	86	95	87	127	53	82	61	74	65	70	92	91	102	115	121	115
609	33	19	51	60	46	10	59	63	13	19	30	30	60	60	73	80	86	94	78	47	117	104	79	93	126	48
610	52	38	70	77	65	29	63	86	19	9	27	11	44	31	70	71	88	91	56	28	119	108	70	84	117	29
611	60	49	79	86	72	40	76	86	30	27	17	38	78	51	99	98	109	120	90	62	140	131	97	111	144	56
612	63	43	81	87	65	40	74	95	30	11	38	10	43	47	69	50	87	78	72	44	118	88	49	63	96	18
613	59	35	77	75	52	54	77	87	60	44	78	43	18	85	68	70	86	74	54	26	117	87	45	59	92	77
614	93	79	111	118	106	70	104	127	60	31	51	47	85	22	111	107	129	132	97	69	160	145	106	120	153	70
701	31	47	42	22	45	64	79	53	73	70	99	69	68	111	5	19	8	11	22	42	39	30	44	52	60	86
702	56	54	71	39	52	73	86	82	80	71	98	50	70	107	19	15	37	40	43	49	68	59	47	61	89	78
703	49	57	50	40	63	76	89	61	86	88	109	87	86	129	8	37	8	29	40	60	31	48	62	70	78	104
704	52	68	63	43	66	85	100	74	94	91	120	78	74	132	11	40	29	14	43	61	60	51	33	41	74	82
705	35	53	54	21	49	68	84	65	78	56	90	72	54	97	22	43	40	43	11	28	67	52	70	84	82	95
706	40	18	60	49	36	37	60	70	47	28	62	44	26	69	42	49	60	61	28	12	91	74	32	46	79	67
707	76	88	81	71	94	107	120	92	117	119	140	118	117	160	39	68	31	60	67	91	16	49	89	101	79	105
708	61	79	80	57	85	94	110	91	104	108	131	88	87	145	30	59	48	51	52	74	49	15	46	50	30	56
709	72	50	92	76	68	69	92	102	79	70	97	49	45	106	44	47	62	33	70	37	89	46	13	14	47	55
710	86	64	104	84	82	83	106	115	93	84	111	63	59	120	52	61	70	41	84	46	101	50	14	12	33	41
711	91	97	110	87	115	116	139	121	126	117	144	96	92	153	60	89	78	74	82	79	79	30	47	33	11	34
712	81	67	99	108	94	58	92	115	48	29	56	18	77	70	86	78	104	82	95	67	105	56	55	41	34	16

Note: These time distances apply to the passenger transportation.
They are based on the railroad operating schedules which have been typical in 1977.
For the routes inaugurated between 1977 and 80, the schedules of typical inbound trains operated during the morning peak hours in 1980 are used. The time required for transfers is fixed at 10 minutes when such transfers can be made at the same station. It will be extended up to 20 minutes when transfers are possible between the adjacent stations.